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Vernalization and Phasic Development of Plants



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Vernalization and Phasic Development of Plants

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CONTENTS.

Foreword : Sir DAVID CHADWICK.

	<i>Page.</i>
Research in the Soviet Union.	7-112
(1) Theories.	9-22
Theory of Lysenko.	9
Theory of Ljubimenko	18
Other theories	21
Bibliography	22
(2) Experiments on the effect of temperature, light and other factors on development	23-45
A. Temperature	23
B. Temperature and light	27
C. Light	33
D. Light and other factors	41
E. Stimulative factors	45
Bibliography	45-46
(3) Biological processes associated with plant development	47-56
A. Diagnosis of the vernalized state	47
B. Distinction between winter and spring forms	51
Bibliography	56-57
(4) Vernalization of various agricultural plants	58-90
A. Technique	58
B. Special crops. Technique and Results	61
Cereals	61
Herbage and Forage Crops	73
Cotton	81
Other Plants	86
Bibliography	90-92
(5) Application of the theory of phasic development	93-111
A. Breeding	93
B. Far North	100
C. Drought Resistance	105
D. Frost Resistance	107
Bibliography	112
Vernalization in countries other than the Soviet Union	113-43
Irish Free State, England, Germany, Czechoslovakia, Poland, France, Italy, Portugal, Sweden, Holland, Greece, Bulgaria, Rumania	115-33
China, India, Ceylon, Burma	133-36
Kenya, South Africa, Mauritius	137
Canada, Bermuda, U.S.A., Brazil, British Guiana	137-42
Australia	142-43
Bibliographies A and B.	144-48
INDEX OF CROPS	149-50
INDEX OF RUSSIAN JOURNALS	151

FOREWORD.

The rapid development in scientific research is one of the outstanding features of the Twentieth Century. It has brought its own difficulties to research workers. Research workers everywhere need the earliest possible information of developments affecting their line of study but frequently find themselves baffled by its volume and by linguistic difficulties. To meet these difficulties, for those engaged in their respective countries in various branches of agricultural scientific research the governments of the British Commonwealth of Nations founded in 1929 a group of Imperial Agricultural Bureaux thereby extending greatly similar action which they had already taken in regard to Entomology and Mycology. Each bureau issues a journal of abstracts in its own field as well as special publications dealing with particular subjects.

In March 1933 the Imperial Bureaux of Plant Genetics at Aberystwyth and Cambridge published a bulletin on "Vernalization or Lysenko's method for the pre-treatment of Seed." Till then little was known of this method or theory. The original papers were only available in Russian, and the very few references in papers in other languages had been extremely brief. The publication of this bulletin attracted widespread interest. The issue was soon sold out. Research workers in practically every European country and also in countries as far apart as Canada, Australia, Ceylon, Brazil and China examined the process and confirmed or challenged the results or theory. Many communicated their observations to the bureaux. Meanwhile close touch was maintained with the Russian research workers.

Owing to the interest aroused, to requests received by the bureaux for fuller information, and to the developments taking place, the present publication has been prepared. It sets out the theories of Lysenko and of other schools of thought, it summarizes the results obtained in Russia and elsewhere as well as the practical application of vernalization so far as that has been tried. It brings all that information as near as possible up to date.

The bureaux wish to acknowledge the help received from workers in many lands who have communicated their results, observations and copies of their papers and so aided in making available to all research workers a thoroughly up-to-date and documented review of a process and a theory of wide interest and likely to provoke much attention, certainly among plant physiologists and geneticists and possibly among others. It is also desired to acknowledge the assistance of Dr. F. G. Gregory, who has read the proofs and made a great number of very valuable suggestions in connexion with the matter and form of the bulletin.

DAVID CHADWICK,
Secretary.

Executive Council of the Imperial
Agricultural Bureaux.

December, 1935.



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Research in the Soviet Union

1. THEORIES.

THEORY OF LYSENKO.

The original theory of vernalization as presented by Lysenko in his first publications and outlined in the Bulletin of the Imperial Bureaux of Plant Genetics in 1933 was tentative and consequently incomplete in many points. Its fundamental principles, while remaining essentially unchanged, were presented in a modified and slightly extended form in the fourth Bulletin of Jarovization in 1932 and on the basis of this it has been possible to give the following brief outline of the theory as Lysenko then viewed it.*

In the first place it must be pointed out that the term "Jarovizacija" is used by Lysenko in two distinct senses: firstly, the word denotes the process of pre-sowing treatment which has come to be known the world over by that name or its latinized equivalent "Vernalization"; and secondly, the first developmental stage which winter cereals are incapable of completing naturally when sown in the spring is also referred to as the Jarovizacija or Vernalization Stage. As this stage is now known to be only one of many, at least two of which can be passed before sowing, a certain confusion has resulted from the double use of the term and in the present bulletin the use of the word "Vernalization" will be confined to the method of treatment; the first developmental stage described by Lysenko as the "vernalization stage" will be referred to as the "thermo-stage," this being the most appropriate designation for the stage for which temperature conditions are the main controlling factors, although in his later writings Lysenko has emphasized that other factors may be equally important in governing this stage, too.

The main principles of Lysenko's theory as stated by him in 1932 were as follows:

(1) *The development of an annual seed plant and the growth of the plant are not identical phenomena.* By growth Lysenko understands the increase in weight and volume of the plant at any particular stage. The complexes of external conditions necessary for the plant to pass through the developmental stages and those necessary for the growth of the plant at any particular developmental stage are often not identical, not only as regards the factors required, but also as to their intensities. Thus for instance spring cereals when sown in spring have all conditions suitable for both growth and development, and complete their reproductive cycle normally. On the other hand when winter cereals are sown in spring the conditions are frequently unfavourable for the completion of certain stages of their development, which is thus inhibited, and the plants appear to remain for an indefinite time at the stage of tillering, i.e. their growth continues but their development is arrested. This distinction between the conditions required for growth and development makes it possible to have conditions which lead to any of the following states:

- (a) rapid growth of the plants but slow development,
- (b) slow growth and rapid development,
- (c) rapid growth and rapid development.

*In December 1934, the Aberystwyth Bureau published a clear account by Professor N. A. Maximov of the principles of Lysenko's theory and its relation to other theories, under the title of "The theoretical significance of vernalization." (*Herb. Publ. Ser. Bull.* 16).

For example, when three sets of an early cotton variety 1306 were sown simultaneously and later grown under different conditions, one set grew rapidly but developed very slowly and eventually produced very tall plants which failed to form flower buds, the second set grew and developed quickly and gave somewhat smaller plants which flowered and produced bolls, and the third set grew slowly but developed very rapidly, yielding dwarf plants which fruited.

The foregoing example indicates that the rate of growth of plants defined as the rate of accumulation of dry matter, in a word the size of the plant, is in no way necessarily an indication of the "development" attained by it.

(2) *Development consists of a series of stages.* Lysenko regards the "development" of the plant as consisting of certain stages following in serial order. These stages are described as "qualitative" changes occurring in the plant, each of which must be traversed before seeding can take place. Lysenko distinguishes between the "morphological" changes occurring during plant development and these "qualitative" stages. The two may or may not coincide: thus some "qualitative" changes may be associated with morphological, though morphological changes do not necessarily imply "qualitative" stages. Each of these stages requires for its completion a definite set of external conditions such as temperature, light, humidity, aeration, etc., and one of these factors, owing to its liability to be absent, tends to assume predominant importance, according to which the stages are appropriately named.

(a) *The thermo-stage of development.* The results of experiments indicate that one at least of these stages, the so-called stage of "vernalization" or "thermo-stage," is completed before the initials of the reproductive organs are laid down, which evidently cannot occur until the said stage is accomplished. The conditions required by the plant for the completion of this stage are low temperature, ranging from 0° to 20°C. according to variety, combined with suitable conditions of moisture and adequate aeration. Experimental study has shewn that the time required for the completion of this stage does not depend upon the size and age of the plant, but only upon its genotype and the environmental conditions. The time required for completion varies with the environmental conditions, but it has been found to vary in a similar manner both for the slightly sprouted seed and for the growing plant and Lysenko states that "the processes conditioning the sexual reproduction of cereals may occur not only in growing plants, but also in a seed with an embryo which has just commenced development but not broken the seed coat." This principle is particularly important, for it forms the basis of the method of vernalization in which the "thermo-stage" is effected not in growing plants, but in seeds which have just begun their development. Experiments have shewn that in order to effect this the dormancy of the embryo must have been broken, for if the seeds have only swollen while their embryos are still in a state of dormancy the treatment will be ineffective and the vernalizing processes will not begin. The embryo must be induced to start growth without being allowed to pierce the seed coat. This leads Lysenko to assume that such seeds have already ceased to be seeds in the physiological sense and have become equivalent to growing plants, though on casual inspection these plants may differ in no respect from resting seed. Although first shewn in the case of winter cereals it is now claimed on the basis of experimental investigation that the principle is of general application and holds for spring cereals and other types of plants, including the thermophilic types such as cotton.

The method of vernalization aims at providing the plant with the necessary conditions for the completion of certain stages before sowing; but since the appropriate environmental conditions for the completion of the stages are different for different plant species and are even found to vary for different strains of the same species, it is necessary in the case of any given plant to determine first of all the

precise conditions required for its rapid completion of the several developmental stages, and the particular set of factors constituting the environmental conditions playing the greatest part in the process of vernalization. Only when this has been determined is it possible to study the exact doses of the different factors required by any new plant under study and to elaborate a detailed method of treatment and only then will it finally be possible to evolve a method suitable for agricultural application and capable of giving the maximum effect in practice.

Some information on the conditions required by certain agricultural plants is already available. Thus, for the completion of the first stage ("thermo-stage") different varieties of wheat require different temperatures. In this respect wheat varieties may roughly be divided into winter, semi-winter and spring forms; the winter varieties require, together with suitable other conditions, a temperature not lower than -2° and not higher than $+10^{\circ}$, the semi-winter not lower than $+3^{\circ}$ and not higher than $+15^{\circ}$ and the spring from $+5^{\circ}$ to $+20^{\circ}$ and over. It must be pointed out that varietal differences within each of these groups in respect of the range of temperatures required are considerable and to divide wheat or any other plants into sharply defined spring and winter groups, as is commonly done in agricultural science, is quite misleading.

(b) *Further stages in development.* The "photo-stage." Until the changes involved in the thermo-stage have been effected, the plant is incapable of reproduction. These changes in themselves are not however sufficient to enable reproduction to be eventually initiated. Before this is possible in wheat and other long-day cereals for instance, a further stage is necessary immediately following upon the thermo-stage, i.e., still further qualitative changes of the plant tissue must take place. This stage can be effected only after the thermo-stage is completed and also requires a set of fixed conditions, different from those required by the preceding stage. For instance, the thermo-stage can only be effected in winter wheat under conditions of reduced temperature and sufficient moisture and aeration: light and darkness play no part in this stage. The second stage on the other hand requires high temperature and can only be effected under conditions of long day or better still of continuous illumination. Thus plants of the winter wheat Novokrymka 0204, vernalized and unvernallized, were grown by E. P. Meljnik under high summer temperature conditions, such that the unvernallized plants could not effect the first stage by the natural temperatures. The unvernallized plants, in spite of having every condition favourable for their development, did not come into ear, whilst the vernalized plants produced normal seed. On the other hand these same vernalized plants when grown in a 10-hour day instead of continuous light also entirely failed to come into ear and appeared to remain in exactly the same condition as the unvernallized plants. Some of these plants were transferred, at different times, to continuous light, whereupon they immediately proceeded to form ears, regardless of the length of time they had been in the shortened day. The unvernallized never came into ear, however long they remained in continuous light. These experiments therefore gave the first indication of the existence of a second developmental stage in which light plays an important part and which is therefore referred to as the "photo-stage." This illustrates Lysenko's fourth principle [(see, however, Section 2A, and McKinney and Sando (p. 139) and Purvis (p. 115)] that plants at different stages of development require different external conditions, and that the external conditions corresponding to one stage of development may be entirely unsuitable for another stage of development of the same plant.

As mentioned above, in the development of the plant a strict sequence is observed in the occurrence of the stages and without the completion of the one developmental stage a plant cannot pass on to the succeeding stage (see, however, Section 2A). This is made particularly clear by Lysenko's example of incomplete vernalization

in the thermo-stage. Wheat seed of the variety *Erythrospermum* 1325/5 was treated for varying lengths of time (7-11-17—... up to 77 days) and grown at high temperatures; only those plants which had been treated for 41 days and more came into ear, the others remaining in the same stage as the unvernallized plants. The time required by the variety quoted for the completion of the thermo-stage was evidently 41 days.

Field conditions are often suitable for all developmental stages but one, in which case the plants proceed up to this stage of development and then cease further development in spite of the fact that conditions are favourable for all later developmental stages. Thus, many varieties of wheat and other plants when sown in spring fail to come into ear, not because the spring and summer temperatures are too high for all developmental stages of these plants, but merely because the temperature is too high for the accomplishment of one single stage, the thermo-stage. When the thermo-stage has been completed these plants can normally complete their cycle of development, terminating with the ripening of seed, as demonstrated by the experiments in which vernalized spring sowings have produced seed normally, but not if grown under reduced length of day. This long day requirement holds not for the entire cycle of development of such plants, but only during the one particular stage through which they must pass immediately after the thermo-stage. The second stage of development in wheat can be most rapidly effected in continuous illumination, less rapidly under the conditions of long day and finally under short day conditions it is delayed indefinitely. For the other stages of development of wheat continuous illumination or a long day are apparently not essential: the length of day neither accelerates nor retards them. Here light is necessary only for photosynthesis. Plants of winter wheat after having passed through the thermo-stage and the photo-stage may effect all the remaining stages up to the development and ripening of seed even under conditions of high temperature and short-day. Since the developmental stages take place in strict succession, as pointed out above, one stage being duly completed before the next can begin, it follows that as regards the plant as a whole and also its individual parts no stage can ever be omitted (see, however, Section 2A, and Purvis, p. 115).

Lysenko has thus shewn that the classification of the different types, such as long-day and short-day, spring and winter, etc., is quite rough and entirely empirical, being based merely on the conditions under which the plants are commonly cultivated. The common classification of plants into spring and winter is therefore entirely unsatisfactory. To speak of the external conditions required for the development of a plant without further specifications often amounts to saying nothing at all. The conditions required for one stage of development have been seen to be quite different from those required by another stage, as in the case of winter plants, which for the accomplishment of one of their stages of development require (together with other factors) reduced temperature (from -2° to $+10^{\circ}$), whilst for all other stages these plants require high temperature. Cotton, a thermophilic plant, requires different temperatures for its different stages. Millet, soya bean, maize and other "short-day" plants require short day (or rather long night) only for one of their developmental stages. All the other stages of development can be effected not only in short day, but in a much wider range of light conditions, often even in continuous illumination. Wheat (and other "long-day" plants) require continuous illumination or even long day only for one stage of development, whilst mostly the other stages of these plants can be effected under conditions of short day. This was shewn by experiments on vernalized wheat, which, after having been retained for 20 days under continuous illumination, developed just as rapidly when grown in a 10-hour day as when retained in continuous light, and came into ear and matured at exactly the same time. Many species of plants or certain of their varieties have been discarded from agricultural practice merely because the

climatic and geographical conditions do not correspond to those required by one particular stage alone of their development. Many winter varieties for instance are unsuitable for cultivation in spring merely because the spring conditions fail to supply the low temperatures necessary for one single stage of development. Spring varieties on the other hand do not need such low temperatures and can be grown with success. However, different varieties both of the spring and winter group require different temperatures and different lengths of time under these temperatures and since the temperature conditions and also the duration of spring are different in different regions it is not infrequently found that spring varieties of certain regions may behave as winter varieties when sown in other regions. Many of the lines of the world collection of wheats which were spring sown in 1932 at Odessa and at Kharkov behaved as typical spring wheats, but when sown in the Central Caucasus in the same year behaved as typical winter wheats. Thus the length of vegetative period is the result of the reaction of the plant to the environmental conditions and there can be no conception of the earliness or lateness of a given variety except in relation to the conditions under which this variety is grown, which again is illustrated by the alteration in behaviour of so many varieties after vernalization.

(c) *Short-day Plants.* With regard to these plants, Lysenko has come to the conclusion that the accepted view of these plants, based on the theory of photoperiodism, is also essentially fallacious. The regions where they grow are characterized, it is true, by equal alternations of light and darkness, just as the regions of the "long-day" plants are characterized by the alternation of long day and short night. From this it has been inferred that the different groups of plants demand an alternation of different periods of light and of darkness. Yet in the case of the long-day plants, it has been shewn beyond question that the most successful development is attained when they are grown in continuous illumination, i.e., without any photoperiods at all. Such plants would thus be more correctly designated not "long-day" plants, but "plants of continuous illumination," for in one of their stages they require continuous light and only tolerate an alternation of light and darkness if the dark period is relatively short. This is a very different formulation of the problem of photoperiodism from that of Garner and Allard and their followers.

Further, the older view maintained that the "short-day" plants require conditions of short day and long night throughout their development, whereas Lysenko has shewn that such plants can pass through all their developmental stages, with one exception, in almost any light conditions, regardless of length of day. The one developmental stage that is particularly affected by light moreover requires continuous darkness, not an alternation of any kind. When subjected during the early stages, after completing the first stage but before sowing, to continuous darkness, together with the other requisite conditions of growth, plants of soya bean and millet have been grown for their entire life cycle, from sowing to seed maturity, in long-day conditions and even in continuous light. Thus even in the case of the short-day plants, any question of the necessity of photo-periods is ruled out. They require only 10-15 days of darkness or short day and after that can develop equally well in a long or a short day. This group of plants would therefore be more correctly styled "plants which in one of their developmental stages require darkness or low light intensity." Just as the long-day plants can tolerate a certain amount of darkness, so these plants can in the stage requiring darkness tolerate a certain alternation of light and darkness, provided that the light periods are not too long. Thus they can normally be cultivated only in southern districts. By giving them the necessary 10-15 days darkness in the pre-sowing stage, however, when the seeds have just begun to germinate, these plants can be induced to pass the photo-stage and can achieve all their subsequent development perfectly well under northern conditions.

Such pre-sowing treatment thus makes it possible to cultivate southern short-day plants in northern regions where according to the theory of photoperiodism their cultivation would be quite impossible.

(3) *Interpretation.* From the point of view of the interpretation of the phenomenon of vernalization the experiments on partial vernalization previously referred to are instructive. Vernalized plants could be kept for any length of time in a 10-hour day, yet when transferred to continuous light gave immediate ear development, whilst unvernallized plants never did so. This again shews that the qualitative changes occurring in the cells of the embryo at the time of vernalization constitute some permanent change of state which is transmitted to all later generations of cells throughout the life of the plant. Thus although the vernalized and unvernallized plants are externally alike, their tissues are nevertheless qualitatively different. The same is true with regard to the photo-stage, and plants that have been in continuous light for 20 days can then complete their development even in short day, shewing that the qualitative changes occurring during these 20 days are sufficient to have altered the entire plant tissue, this change being again transferred to all later generations of cells produced. Moreover, in the above experiments the plants that had been insufficiently vernalized in the thermo-stage were induced to come into ear by giving them a further cold treatment of just so many days as they were short in the first treatment. The time of additional treatment moreover was found to be uninfluenced by the period during which the plant had been left between the two treatments and to depend only on the number of days missed in the first treatment. Thus seed material of varieties requiring 45-50 days has frequently been treated for say 40 days and retained in a dried state until required and then given the remaining period immediately before sowing. The fact that degrees of vernalization can be retained in this way shews that vernalization is a gradual process, consisting apparently of an accumulation of qualitative changes, all of which are retained in the cells in which they occur and transmitted to later cells formed from them. For the completion of these processes different varieties require very different lengths of time, e.g. in wheat, *Erythrospermum* 8081/8 requires 18 days, *Kooperator* 40 days, *Stepnjačka* 45 and *Ukrainka* 50; but once the process has been carried to completion by treatment for the requisite length of time no amount of further treatment has the least effect on the plant.

Thus the process of vernalization in the thermo-stage consists of a succession of gradual quantitative changes up to a certain well defined limit and until this limit is reached it is impossible for the following stage to begin. Various experiments have been made to discover whether these changes occur in the entire plant or only in localized sections of the plant, e.g. in the growing point. These experiments have been performed mainly on soya bean and cotton plants. When cuttings were taken from a soya bean plant at successive points along the stem, the plants obtained from them behaved differently: those from cuttings taken from above the point of insertion of the first flowering shoot all came into flower almost immediately, whereas those from below the first flowering shoot were very much delayed in flowering and the delay was greater according to the distance below the flowering shoot at which the cutting was taken. The same phenomenon was observed in cotton plants which after fruiting were maintained in a greenhouse over the winter: in the following spring they began to form new leaves and sympodial branches in their axils, but the sympodial branches here again were formed only in the axils of the leaves appearing above the point of insertion of the first sympodial branch of the previous year; below this point only monopodial, vegetative, branches were formed. This occurred even when the upper branches, above the first sympodial shoot, were cut off, shewing that it was not the insufficiency of nutritive materials that prevented the lower

branches forming flowers, but rather some quality of the cells composing them. Further, two soya bean cuttings were grown in continuous light, one being taken from a sterile plant grown in continuous light, under which conditions soya beans do not normally flower, the other from a plant that had been grown under normal conditions and flowered. The cutting from the non-flowering plant formed no flower buds during the whole time it remained in continuous light, whilst the other cutting from the flowering plant rapidly formed flowers and developed fruits. From these experiments it is concluded that the formation of reproductive organs is not governed by the supply of nutritive materials, nor by the position on the plant, but depends entirely on whether the cells of the tissue in question have undergone the particular changes which are necessary before reproduction can be initiated. The cuttings from successive points along the soya bean stem flowered gradually earlier as they were taken from points higher and higher up the stem, i.e., from younger tissue, indicating that the older the tissue, the less it has progressed in the preparation towards maturity. In other words in the life of the plant and of its individual organs there is a gradual completion of those changes which constitute the different developmental stages, in such a way that the changes are most nearly complete in the youngest tissue. The tissues of the lower parts of the plants had actually been for a longer time under the conditions which favour the qualitative changes concerned, yet by their behaviour they shewed themselves to be as little changed as the tissues of a young plant which had never been under these conditions at all. From this it is argued that the changes occur only in the cells of the growing point, occurring gradually until the limit, represented by the completion of the stage in question, is attained (cf. Ljubimenko, pp. 18-21.) Once the changes have occurred in the growing point, however, they are transmitted to all later formed cells from that growing point, so that a plant may be formed in which its different parts are at different stages of preparation for reproduction. Thus the position at which the first reproductive organs appear on the plant varies with the rapidity with which the qualitative changes, on the one hand, and the growth of the plant, on the other hand, occur under the particular conditions in which it is grown. In cotton, for instance, the first sympodial branches generally appear in the axil of the fourth to sixth leaf, but plants have been observed which, when grown under conditions particularly favourable for the developmental stages and unfavourable for growth, have formed sympodial branches in the axil of the second leaf, whilst others grown under the reverse conditions have formed 25 to 30 leaves without producing a single sympodial branch. The same position has been observed in soya bean, *Hibiscus cannabinus* and other plants.

These considerations form the basis of the method of vernalization, in which conditions are so regulated as to provide the optimum conditions for the developmental processes and at the same time prevent growth altogether in a young plant which has only just begun to develop from dormancy. By this means it has been possible in some plants to complete both the first and second developmental stages before sowing and soya bean plants have been obtained which after pre-sowing treatment have shewn accelerated flower formation even when grown in continuous light, and have moreover formed their first flower bud at a lower level than the normal, quite often in the axil of the first leaf.

In view of this interpretation of the process of vernalization, it becomes especially important to make observations on different tissues known to have reached different degrees of vernalization, in order to find a reliable method of diagnosis whereby the precise state or degree of vernalization may be determined, microchemically or by some other simple method, so obviating the necessity for applying the direct test of behaviour which hitherto has been the sole criterion. (See Section 3.)

able to complete the photo-stage, as is confirmed by the fact that they eared simultaneously in spite of the different lengths of day of the subsequent growing period. In the plants grown under the 12 hour day for 44 days (series B) the photo-stage had just begun, for after 34 days' exposure to the differentiated length of day the rudimentary ear was found only on the plants of the 12 hour variant and not on any other variant of this series. In the plants that were first grown under a 10 hour day (series C) no sign of the completion of the photo-stage was observed, for after exposure for 34 days to the differentiated day these plants did not form stems or rudimentary ears. Thus as a result of growing plants of this series under different lengths of day, the plants had reached the following stages: (1) both the thermo-stage and the photo-stage completed (series A); (2) the thermo-stage completed and the photo-stage just commenced (series B) and (3) the thermo-stage completed (series C).

A study of the gametophyte shewed that gametogenesis had been completed only in the plants of series A. In all variants (with the exception of the 2 hour variant) of series A, anthers containing pollen grains had been formed. The fertility of the pollen was as follows: the 2 hour variant formed no pollen, the 4 hour variant began to form pollen and a few grains were found in the anthers, the 6 hour variant formed a larger amount of pollen and set seed and with increasing day length increasing pollen fertility was observed, the 12 hour variant being quite normal.

The absence of fertile pollen where observed is to be explained not so much by light starvation as by the fact that the cells of the gametophyte did not pass through the necessary qualitative changes (as understood by the theory of phasic development) which must precede gametogenesis. The authors, therefore, consider that the stage of development which is required for normal pollen formation was not passed in the 2 hour variant and only partly completed in the 6 hour variant. In the 4 hour variant the stage associated with the formation of the reproductive parts had just been commenced, as is confirmed by the fertility of a small amount of pollen which was found deeply embedded in the anthers, although it was unable for various reasons to escape from the anthers and thus be available for fertilization.

It was, therefore, considered that the formation of normally functioning gametes depends upon some preliminary phasic changes in the cells of the gametophyte and that these changes represent a separate developmental stage following the photo-stage. (See also Ljubimenko, pp. 18-21.)

In 1934 the investigation was extended by Kiričenko and Bassarskaja (1 and 2). *Triticum erythrospermum* 534/o was used after vernalization. After germination the plants were exposed for one month to continuous illumination, and then exposed as before to varying periods of light per day. All the plants produced stems and ears, shewing the effect of continuous light in the completion of the photo-stage. The plants exposed to 4 hours of light were sterile. It was found, however, that this sterility could be overcome by exposing the plants to long-day conditions for 2-4 days at the appropriate moment (after the completion of the photo-stage) and even with a daily light exposure of 4 hours the plants would set seed. Thus plants which have passed through the photo-stage need not necessarily be exposed to further long days, and it was found that plants that have completed the first two stages will when grown under an 8-hour day come into ear at the same time as those grown under continuous illumination. Though both the photo-stage and the stage succeeding it require light therefore, the durations necessary evidently differ, the former stage requiring light of long duration and the latter being satisfied with a short day. The discovery of this further light stage following immediately on the photo-stage strongly corroborates the present view of Lysenko that the three developmental stages are not isolated units but consist each of several sub-stages. The discovery of the third stage is expected to have an important bearing on the pollen

sterility frequently observed in greenhouses during the winter. It will probably be possible also "to differentiate plant varieties on the basis of the character and duration of this stage, which will be a factor of great practical significance in the appropriate selection of parental forms in hybridization." Other aspects of the application of the principles of vernalization to breeding are dealt with in section 5.

THEORY OF LJUBIMENKO.

Before passing on to an elaboration of the effect of the different environmental factors on the stages of plant development (see section 2) it may be appropriate at this point to consider the theory of Ljubimenko and his school, which in many essentials differs from that of Lysenko (4 and 5).

Ljubimenko points out that the method of controlling the time of fruit production by chilling was first practised in Russia by the agronomist Gračev with artichokes and maize as early as 1875. The existence of photoperiodism was also discovered some time ago, in 1912, by a French botanist, Tournoi, working with hops. Almost all the main facts elicited by the present theories of vernalization and photoperiodism were arrived at by Klebs, who emphasized the possibility of controlling reproduction by external influences, in opposition to Pfeffer, who claimed that internal influences alone were responsible. The particular importance of temperature and light was demonstrated by Klebs, who also arrived at the conception of a condition of "ripeness to flower," the "blühreifer Zustand," which is a purely internal state not associated with any morphological peculiarity of the plant.

The priority in this respect must therefore undoubtedly go to Klebs. He, however, interpreted these phenomena on the basis of the nutrition of the plant, regarding development moreover as a mere consequence of growth, and growth of nutrition.

Thermal and photoperiodic induction.

Experiments have now succeeded in demonstrating clearly that growth and sexual reproduction are entirely different processes, the latter being not an accumulation, but rather a distribution of materials in special reproductive branches; hence entirely different conditions from those favouring growth are required for flowering. In multicellular organisms the time at which reproduction occurs is influenced not merely by the rapidity of cell division, but by the rate of differentiation of the cells and tissues. In the plant kingdom as a whole great variation is observed in the relative rates of growth and of development in the different plant types, and in many of these, namely, the perennials, the formation of reproductive organs does not terminate the life of the individual. However, in almost all cases an acceleration in development is attained by a reduction in size or a simplification of the vegetative organs, i.e., by a curtailment of the generations of somatic cells. By the action of various agencies the number of generations of somatic cells intervening between the zygote and the reproductive cells has been reduced. As each young cell is initially capable of forming any organ of the plant, the development of the cell must be controlled by the influences it receives from without, including the influence of the neighbouring cells and of the organism as a whole. The reproductive phase is not a phase subsequent to the vegetative phase as it has been regarded by some authors, who seem to consider that by hastening the vegetative phase a more rapid transition to the reproductive phase should accrue. In all plants with more than one axis, and in perennial plants in particular, the reproductive and vegetative phases are present together and frequently progress concurrently. The only time at which the vegetative phase alone is present is in the embryo, and in the seedling immediately after germination, before any reproductive differentiation has occurred.

Once special reproductive shoots are formed, the two phases of development and growth proceed together, the latter being represented by a quantitative increase in the protoplasm and the former by a latent, and probably gradual, alteration in its structure and chemical composition. A further characteristic of the reproductive sections of the plant is a tendency to simplification as regards the differentiation of the tissues. It is this morphological difference which is thought to be responsible for the common view of the reproductive phase as an independent, qualitatively different stage subsequent to the vegetative stage. This is clearly fallacious and Ljubimenko regards the differentiation of the flower from the rest of the plant as in no way distinct from the differentiation of other organs such as leaves, etc. Owing to the nature of the changes occurring in development, it is possible to accelerate or retard them long before the time of the actual morphological differentiation which they evoke, and this is why the phenomenon is referred to as "induction." There seems no reason why intervening somatic cells should not be almost indefinitely curtailed, so that the zygote might develop almost directly into reproductive tissue, excluding the vegetative phase altogether, except that a certain amount of vegetative activity is already induced in the embryo with which we start. If the process of induction were started from the moment at which the zygote came into existence by fertilization this difficulty might be overcome. In this connexion the experiment of Voskresenskaja (see p. 44) on potatoes in which a flowering shoot was obtained direct from the tuber is significant, and suggests that the production of flowering shoots in a similar way direct from the zygote should be equally possible in practice.

All this makes it very clear that reproduction is not to be regarded as a stage subsequent to vegetative development, but as a distinct process occurring independently of growth. The growth process is one of quantitative increase resulting from nutrition, not in any way connected with cell differentiation, which is the basis of development. This is illustrated by experiments in which by cutting off the cotyledons of pea seedlings, minute plants were obtained, which nevertheless formed flowers. Similarly the leaves were removed from young lupin plants, which plants nevertheless flowered at the same time as the normal plants, though each bore only one flower. Plants from which only one leaf blade was removed grew somewhat larger and produced several flowers. Thus growth exerts an influence only on the quantity of flowers produced, but plays no part in determining whether flowering shall occur or not. The instance of many vegetatively propagated plants is given to illustrate that growth can continue indefinitely without development of reproductive organs, and of parasitic flowering plants to illustrate the converse phenomenon of uninterrupted reproductive activity without vegetative differentiation and growth. This conception has been amply substantiated by the work on vernalization and photoperiodism, where by a comparatively short treatment with suitable temperatures and light it has been possible to induce the plant to accelerate or retard the alternation of growth and reproductive phases, the essence of the process lying in the fact that growth processes are artificially kept at a standstill while the developmental processes progress rapidly and the plant is thereby enabled to proceed to reproduction. The influence is exerted some time before the differentiation of the reproductive organs, for which reason these effects, too, are referred to by Ljubimenko as photoperiodic and thermal induction. The exact nature of the effect is not yet known, but it seems to consist in some chemical or enzymatic change in the protoplasm or possibly some change of a physical nature.

The experiments of Bojanov and Moškov on *Robinia pseudoacacia* illustrate the above point of view. Reduction in the length of day induced earlier maturity in the vegetative shoots, as a result of which the trees were more hardy. The effect of the reduced length of day resulted in shorter shoots, and stimulated the formation of corky tissue—hence reducing the amount of vegetative growth and stimulating

cell differentiation, thus the state of rest was arrived at more rapidly. Thermal and photoperiodic induction consist not in the specific preparation of the plant for reproduction as stated by Lysenko, but in an acceleration of the entire developmental process, attained by means of a retardation of cell division and acceleration of cell differentiation. By maintaining the external factors at the requisite levels, both the vegetative and reproductive differentiation can be accelerated or retarded together. There has in fact been observed a clear adaptation of the vegetative as well as reproductive organs to such influences as the length of day: *Robinia* has been seen to reduce its vegetative organs in reduced length of day, whilst other trees are known to increase them. Similar secondary changes in vegetative development have been observed with thermal induction (e.g. increased tillering) and evidently account for the yield increases observed by Lysenko in vernalized wheat.

Reversibility of vernalization.

Ljubimenko also differs from Lysenko in his interpretation of the change occurring during vernalization. Lysenko regards this as a gradual qualitative change in the protoplasm, basing his conclusion on the existence of partial vernalization both in the first and second stages. If these gradual qualitative changes exist, however, there must be a whole series of them, each with a corresponding length of vegetative period, for Ljubimenko quotes experiments which have shewn that by different combinations of long and short day it is possible to induce all possible variations of the vegetative period in soya bean, from a minimum of 26 days to a maximum of 98 days. This can, however, be explained by a series of secondary changes in the protoplasm, of a quantitative nature, superimposed on the qualitative change whereby the protoplasm acquires the ability to form reproductive organs and without which it is capable of producing only vegetative tissue. Lysenko regards the "qualitative" change discussed by him as permanent and irreversible, but experiments are mentioned which throw doubt on this assumption also. Parthenogenesis and various teratological cases are cited in proof of the interchangeability of vegetative and reproductive tissues and reference is further made to experiments with soya bean. The plants were subjected to a 6-hour day for 21 days after germination, upon which they were transplanted to normal conditions. The treated plants flowered and formed fruit, while control plants untreated did not even come into flower. The flowers, however, were only formed on the main axis which had been exposed to the reduced day length: the lateral branches which had developed after the transplantation to the long day produced no flowers. This shews that the change induced by the short-day treatment is not transmitted to all later generations of cells, as maintained by Lysenko, but is impermanent and reversible. (See also Konstantinov, p. 40, Litvinov, p. 39, Gavrilova, p. 49, Čepikova and Zerling, p. 79, Novikov, p. 82 and also Bassarskaja, p. 47.)

The reversible nature of the process of induction is still more clearly illustrated by certain experiments of V. V. Botvinovskii and O. A. Ščeglova, where *Perilla ocymoides* was induced to flower by induction under short days, but when it was transferred to long day again flowering ceased. For instance, a plant which for a month from germination was kept in a 10-hour day and was then replaced in normal daylight began to flower on the 48th day from germination, but after 13 days the flowering again ceased for 28 days, after which it recommenced. The control plants grown in normal daylight flowered only after 88 days from germination. By similar treatment with a 7-hour day the plants were induced to flower on the 34th day from germination; flowering continued for 18 days and then ceased again until the 27th September, 92 days after the first flowering. The second flowering in each case was due to the naturally reduced day length occurring in Leningrad in September.

Thus a succession of reproductive and vegetative phases was obtained analogous to those of perennial plants.

These experiments leave little doubt that the process of induction is a reversible one. In the brief intervening period between the two phases, tissue induced both vegetatively and reproductively may exist side by side and lead to the formation of abnormalities, a number of which have been obtained by O. A. Walter in hemp (unpublished).

The removal of induction has also been achieved by Tolmačev by the use of X-rays, in the case of the wheat variety Ukrainka, after vernalization and these results are quoted as demonstrating the reversibility of the process of vernalization.

There thus seems then to be a period in the life of a young cell when it is "labile" or capable of being induced in one direction or the other; after this period is passed, however, the induction is fixed—the cell attains a "stable" state and continues to produce offspring all of one kind, being induced in one direction or the other, and forming either vegetative or reproductive organs.

Hormones.

The inductive action of length of day and the absence of any such effect by adjusting the light intensity are explained by the existence of a developmental hormone, whose action is inhibited by light even of quite low intensity. Under the influence of conditions inhibiting or reducing the action of the hormone its effect on the protoplasm ceases and this accounts for the loss and reversal of induction described in the experiment on photoperiodism. The nature of the hormone in long-day plants and especially in intermediate plants remains a matter of speculation. The different reactions of the various plant groups to thermal and photoperiodic inductions are considered to be adaptational, having resulted from long continued natural selection over innumerable generations during the evolution of the various species. In consequence of this it will usually be found that the thermal and photoperiodic adaptations go side by side, so that northern plants will be favoured in their development by a combination of chilling and long day, and if either of these factors is absent development is retarded or even inhibited.

Third Stage.

Plants of melon and water melon, chosen on account of their unisexual flowers, were also exposed to a 6-hour day for 25 days and then removed to natural daylight. The short day induced a reduction in length of stem which was not made up during the later growth in long day; this was also associated with a reduced number of leaves. The reaction was therefore similar to that of the soya bean. On the other hand, flowering in the water melon was retarded by ten days, the water melon being possibly a long-day plant. The early melon variety used was accelerated by 14 days.

A more important difference was in the nature of the flowers produced: the control plants bore only male flowers whereas the treated plants began by producing male but soon bore also female flowers, which ultimately formed fruit. Male flowers are invariably formed before female flowers and the effect of the induction is thought to be not the reversal of the sex of the flower, but a curtailment of the period between the formation of male and female flowers. The process seen in the earlier development of the plant, consisting of the acceleration of reproduction associated with a reduction of the vegetative organs, is here extended therefore to the individual stages of flowering. The treatment was applied only after the formation of the first leaf and it is thought that it would have been more effective still if applied before the plant had received any long day influence at all. (See section on third stage, pp. 16-18.)

OTHER THEORIES.

With these two opposing theories, the proposed explanations of phasic development are not exhausted. Pivnovskii (7) has made experiments on the effect of environmental factors such as light, soil humidity and manuring on plant development and arrived at a theory of phasic development in general principle resembling that of Lysenko. In Pivnovskii's theory, the details of which are given on p. 41, four stages are distinguished, namely, seedling, tillering, seed formation and maturity. Each of these stages requires different complexes of external conditions for its completion and the conditions required for one stage may be the direct opposite of those required for another.

Finally claims that vernalization can be effected by light alone have been made by Čailahjan, Vasiljev and others, whose results are discussed in Section 2 below.

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2.—EXPERIMENTS ON THE EFFECT OF TEMPERATURE, LIGHT AND OTHER FACTORS ON DEVELOPMENT.

A.—TEMPERATURE.

Dolgušin and Lysenko 13*.

Early work on the thermic factor.

In an early work on "influence of the thermal factor on the duration of developmental phases in plants," Lysenko (21) stated that the time required for the completion of some of the phases in cereals such as seedling emergence, ear emergence, earing, wax ripeness, etc., is inversely related to temperature, i.e., the higher the temperature, the more rapidly are any of these phases completed. The phase of "shooting" (ear formation and elongation of internodes), however, in spring and, particularly, in winter forms does not always shew this relation; with the increase of temperature in some cases it is initiated earlier, while in others it takes place later or not at all, so that the plants persist at the tillering or "rosette" stage. "In the latter case we are faced with 'hibernalism' (winter habit of cereals), i.e., the property of plants to remain for an indefinitely long time at the phase of tillering without forming stems." This preliminary communication concerns only that part of the experiments conducted by the authors since 1926, which deals with this property of hibernalism in cereals and the difference between winter and spring forms.

Field experiments on the time of sowing of winter and spring cereals sown every tenth day from August 24, 1926, to August 27, 1927, and from October 17, 1927, to June 1, 1928, shewed that under the conditions at Ganja (Azerbaijan) there is no definite date of sowing after which all winter forms will exhibit the property of hibernalism, i.e. cease to form ear and stems, while spring forms still continue their development. Moreover, different varieties begin to exhibit this behaviour after different dates, and in 1927 and 1928 the same variety shewed different critical sowing dates. March was colder in 1928 than in 1927, and consequently cereals in 1928 began shooting after later sowing than 1927. The later the sowing, the greater was the number of varieties which exhibited the property of hibernalism, in other words, in the late sowings spring forms behaved as winter forms. No clear distinction can thus be made between spring and winter varieties of cereals. It was found that under the conditions at Ganja there are only a few true spring forms and that the shooting of cereals depends upon the date of sowing.

In order to investigate the significance of the thermal factor and how far it determines the critical sowing date for each variety, after which "hibernalism" occurs, the following groups of experiments were made:—

(1) Pot experiments with winter rye were made to investigate the effect of natural winter chilling of varying duration on shooting. Three rye varieties (Schlanstedt, Nemerečanskaja and Petkus) were sown on November 27 in 55 pots; after the appearance of seedlings (December 10), 5 pots of each variety were kept throughout in the laboratory, while the remaining pots, starting from December 20, were removed in groups of five to the open every tenth day and kept there until the normal sowing date. The temperature in the laboratory during December to February was 6-8°C. and during March 8-10°C.

All the variants of these three varieties came normally into the shooting stage. Pots which were kept indoors throughout began shooting on April 15 and the pots brought inside on March 20 began shooting on June 5; the intermediate variants

*Numbers in headings refer to bibliography at end of respective section of Bulletin.

did so in the interval between these two dates. Thus, the longer rye was chilled the later it began shooting, and low temperature is evidently not required for rye to commence shooting. This fully corroborates the results obtained by some other investigators.

(2) The second group of experiments was made with spring chilling of slightly sprouted or swollen seeds of local barley (*H. pallidum* 419) and winter wheat (Koooperatorka). The seeds were divided into three lots, one of which was kept dry in the laboratory while the other two were soaked. One of the latter was only just swollen and the other slightly sprouted. On March 2 the two latter were put in sacks and kept in the snow until sowing, the temperature in the sacks being $+2.5^{\circ}$ to 3.5°C . On every second day from March 4 a small amount of seeds from these three lots was sown, part in the field until June 1 and part in pots in the laboratory until March 30. The results of these experimental sowings are summarized in Tables 2 and 3. Since slightly sprouted seeds and swollen seeds gave similar results, they are regarded as one variant, i.e. experimental (chilled in snow). In addition to these sowings, two others were made in the field, namely, on April 3 samples from all three lots of barley and wheat, and on April 30 seeds of the same barley and wheat which had been kept in snow from April 7.

The results of experimental and control sowings of Koooperatorka summarized in Table 2 shew that the plants from control (unchilled) seeds sown in the laboratory after March 6 and in the field after March 10 did not shoot and continued tillering; in other words March 10 was the first sowing date on which these plants ceased to shew the spring habit. Seeds kept under snow until sowing gave plants which began shooting; the percentage of plants which formed ears was larger under colder field conditions, smaller in laboratory sowings and fell rapidly with the lateness of sowing, though the duration of pre-sowing chilling was at the same time increasing. It might be thought that in later sowings another factor, e.g. the duration of daylight (as assumed by Maximov and Pojarkova, p. 28), counteracted the favourable influence of low temperature, but the increased percentage of shooting plants in the latest sowings (after April 5) contradicts this assumption

Table 2.

Koooperatorka.											
Number of sowing	Date of sowing	Percentage of plants which reached ear emergence.				Number of sowing	Date of sowing	Percentage of plants which reached ear emergence.			
		Chilled		Unchilled				Chilled		Unchilled	
		In labor-atory	In field.	In field.	In labor-atory.			In labor-atory.	In field.	In field.	In labor-atory.
1	Mar. 4	68	100	93	56	12	Mar. 26	46	45	0	0
2	" 6	63	100	85	41	13	" 28	52	53	0	0
3	" 8	38	100	70	0	14	" 30	40	51	0	0
4	" 10	36	79	10	0	15	April 1	} not sown	48	0	} not sown
5	" 12	27	78	0	0	16	" 3		30	0	
6	" 14	62	62	0	0	17	" 5		44	—	
7	" 16	17	64	0	0	18	" 7		85	0	
8	" 18	20	74	0	0	19	" 9		100	0	
9	" 20	34	63	0	0	20	" 14		100	0	
10	" 22	10	55	0	0	21	" 19		100	0	
11	" 24	50	53	0	0	22	" 26	100	0		

(Cf. however Lebedinceva, p. 28). On the whole it may be concluded that the pre-sowing chilling of seeds is favourable for shooting. The plants sown on April 30 with seeds kept under snow from April 7 did not shew any trace of reproduction.

Thus, in defining the significance of the thermal factor for "hibernalization" of Kooperatorka, the authors consider that "the higher the temperature of the after-sowing period, the smaller is the percentage of plants which begin shooting, unless their seeds are kept in snow for not less than 38 days (from March 2 to April 7); after this period of chilling, Kooperatorka behaves in all sowings as a typical spring form."

Experiments with barley gave very similar results, summarized in Table 3. Control sowings (earlier in the laboratory and later in the field) did not shoot and behaved as winter forms, whereas in plants of the experimental sowings shooting was fairly complete and simultaneous. In these experiments also shooting was delayed with the increase of after-sowing temperature. Owing to the low temperature of the after-sowing period, all early field sowings of control seeds began shooting almost simultaneously with the experimental plants. Moreover, plants of all field sowings (up to 16) of chilled seeds began shooting almost simultaneously (on May 8-11), whereas in those sown at the same time in the laboratory at a higher temperature shooting was delayed; the greatest delay occurred in sowings 10 and 11.

Table 3.

Local winter barley (*H. pallidum* 419).

Number of sowing	Date of sowing		Date of ear emergence.				Number of sowing	Date of sowing		Date of ear emergence.			
			chilled.		unchilled.					chilled.		unchilled.	
			in lab.	in field.	in field.	in lab.				in lab.	in field.	in field.	in lab.
1	March 4	May 12	May 10	May 11	May 15	12	March 26	May 13	May 10	}	}		
2	" 6	" 13	" 11	" 14	" 13	13	" 28	" 14	" 10				
3	" 8	" 11	" 10	" 11	" 29	14	" 30	" 12	" 10				
4	" 10	" 12	" 10	" 11	June 3	15	April 1		" 10				
5	" 12	" 10	" 16	" 16		16	" 3		" 11	}	}		
6	" 14	" 15	" 9	" 18		17	" 5		" 14				
7	" 16	" 15	" 8	" 24		18	" 7		" 15				
8	" 18	" 14	" 8			19	" 9		" 15				
9	" 20	" 13	" 10	}	}	20	" 14	}	" 20	}	}		
10	" 22	" 17	" 10			" 19	21		" 19			" 25	
11	" 24	" 18	" 10			" 26	22		" 26			June 2	

Plants of laboratory sowing 14 (on March 30), however, began shooting almost simultaneously with plants on the field sowings, i.e. after 28 days chilling (from March 2 to March 30) the high temperature of the after-sowing period did not retard their development. This is confirmed by the results obtained in the sowings of April 3 and 30 with seeds chilled from March 2, namely, plants shewed a complete and simultaneous shooting. Plants sown on April 30, however, with seeds chilled since April 7 did not shoot, i.e. the pre-sowing chilling of 23 days at a temperature

of 2.5° to 3.5°C. was insufficient. Since sowing 14 began shooting with little delay, it can be assumed that high temperature did not retard plant development, if the seeds had been chilled for not less than 28 days prior to sowing.

(3) Experiments with autumn chilling of slightly sprouted seeds were made to shew that cereals can begin shooting not only when sown in spring or summer, but also in autumn, if their seeds are chilled before sowing. For the sake of convenience only those cereals were used which do not shoot when sown late in spring, namely, *T. durum* var. *apulicum* 2639, *T. durum* var. *leucurum* 1273, *Avena grisea* 570, and *A. byzantina* 952. Sprouted seeds were chilled from August 19 to September 8 on ice and then sown together with unchilled (control) seeds. At the beginning of November, plants from chilled seeds of the wheats and *A. grisea* had begun to shoot, and those of *A. byzantina* to ear. The control plants of the same varieties were still at the rosette stage. Thus, cereals which behave as winter forms when sown late in spring can shoot when sown in summer or autumn, if their seeds are chilled prior to sowing.

Summarizing the results of these experiments, the authors draw the following conclusions:

(a) Experiments on the time of sowing shewed that there are no definite dates dividing winter from spring forms; the later the sowing, the larger is the number of cereals which retain the winter habit. For instance, when sown in the second half of April or later under Azerbaijan conditions not only all the winter and alternative forms, but also the majority of spring forms persisted at the phase of tillering.

(b) One of the main factors preventing shooting is the high temperature of the period subsequent to sowing. However, after a pre-sowing chilling of slightly sprouted or swollen seeds at 2.5° to 3.5°C. for a definite period (for instance for Kooperatorka, 38 days, and for winter barley 28 days), winter cereals when sown at any time will proceed to the shooting stage. After such a pre-sowing treatment the rapidity of shooting increases with the temperature of the after-sowing period. Since the high temperature of the after-sowing period retards shooting in plants sown with unchilled seeds, the authors argue that in cereals during the period from seed swelling to ear emergence there are two "biologically consecutive" phases. The first of these does not produce any morphological changes in the plant and is directly related with the thermal factor, namely, the higher the temperature, the longer is its duration. The duration of the second phase (shooting) is, like all other phases, inversely related to temperature, so that the higher the temperature the quicker is the progress at this phase.

(c) Thus, the retardation of shooting in cereals associated with a high temperature of the after-sowing period is due to the prolongation of the preceding phase; if the temperature of the after-sowing period reaches a maximum at and beyond which the preceding phase for a given variety of cereals cannot be passed, then this variety will behave as a winter form, i.e. will not ear.

(d) Since the temperature rises with the approach of summer, it is observed in sowings of a collection of varieties that the later the sowing the greater is the number of varieties which change from the spring to the winter habit, i.e. the thermal maximum preventing the progress of the preceding phases varies in different varieties.

(e) By comparing the records of temperatures during the authors' experiments with the length of the interval required for the progress of this developmental phase, it was found that their relationship can be expressed by the formula

$$n = \frac{A}{B-t}$$

where n is the duration of the phase in days, B is the maximum temperature beyond which the phase will not progress, and t is the average daily temperature. A therefore represents the sum of the differences between B and the daily environmental temperature during the duration of the phase.

(f) The values of A and B are regarded as characteristic constants for different varieties of cereals; thus, for Kooperatorka wheat, $A=300$, $B=12^{\circ}\text{C}.$; for *H. pallidum* 419, $A=350$, $B=15^{\circ}\text{C}.$ These values, though not exact, closely approach the figures.

(g) Winter and spring varieties of cereals differ only in respect of the value of these thermal constants B and A , i.e. there is no virtual difference between spring and winter varieties. Every variety therefore is to a greater or less extent a winter form as determined by the value of its thermal constants. If during the after-sowing period the sum of differences between B and the actual temperature reaches the value A characteristic of the variety, then that variety will ear no matter when it is sown.

(h) To pass through the preceding phase winter cereals do not need a temperature of $0^{\circ}\text{C}.$, but can do so at a relatively high temperature provided the maximum B for a particular variety is not exceeded. The nearer the temperature approaches the maximum B , the longer will be the duration of this phase as is seen from the given formula.

B.—TEMPERATURE AND LIGHT.

Tolmačev 27.

Early work on temperature and light.

This paper is of early date and is of considerable historic interest. The effects of the various factors such as moisture content of the seed, low temperature, and light are considered.

Seeds of winter wheat were moistened for different lengths of time, 3, 6, 10 and 24 hours, bringing them to a moisture content of 24, 30, 35 and 47 per cent of their dry weight, after which they were maintained for two months at a temperature of about $0^{\circ}\text{C}.$ They were sown very late, at the end of May, 1928, and only those moistened for 24 hours attained full development and formed mature ears.

This is explained on the basis of variation in physiological activity, the accumulation of katabolic products necessary for the formation of the stem and ear; whether this occurs in the growing plant or in the germinating seed is immaterial.

The importance of low temperature is stressed, and the differences between varieties of wheat in their requirements as regards exposure to cold are experimentally established. Bolting in sugar beet is shewn also to be determined by the temperature of germination.

Certain biochemical observations during the pre-sowing treatment were made on the germinating seed. These included increase in acidity and accumulation of catalase and amylase.

With regard to light, it is concluded that the difference between the varieties in their behaviour when spring sown is conditioned by their different response to light, which is thus the principal factor in the preparation of the plants for flowering. Besides the requisite amount of light the plants must have also a minimal period of chilling, since those chilled for less than three to four weeks failed to form ears in the case of the variety Ukrainka. The rapidity of earing increased with increasing doses of chilling and at the same time the yield and quality of the grain were also raised, though they were never comparable with the same variety autumn sown. Analogous results were obtained with sugar beet, and by growing plants in a warm greenhouse with electric light during the winter they could be maintained in the

vegetative condition for several years without any sign of developing a flowering stem, which however developed at once when any of the plants were transferred to a temperature of $+1.5^{\circ}$ or $+1^{\circ}\text{C}$. Here again the cause was thought to be the accumulation of katabolic products resulting from the reduced activity of the root and leaf systems at the low temperatures.

It was thought possible that the processes occurring under the influence of light and low temperature might be accelerated by the use of a catalyst and experiments to test this were made on sugar beet. Seed of 25 different varieties was treated with phosphoric acid or phosphatic salts for 24 hours before being chilled for one month at 0°C ., controls being treated similarly but with distilled water. Bolting occurred in 12 varieties in the treated plants only and not in the control, in two varieties bolting occurred in both, though less in the control, and one variety bolted only in the control. These results are regarded as establishing the efficacy of phosphatic salts as a catalyst in the process of vernalization.

Maximov and Pojarkova 23.

Length of day and temperature.

Experiments were made on four varieties of winter wheat and one of rye. The conclusion is reached that no winter rest is necessary for winter varieties of cereals to produce ears since by a suitable combination of environmental conditions they can be induced to ear in the greenhouse in the first season. The necessary condition is that they are sown sufficiently early, in which case the cold requirement referred to by Gassner is found not to be necessary. The earing of winter wheat was however earlier in the sowings grown at lower temperatures (2° - 5°C .), the difference being especially marked in the later sowings; thus in the very late sowings the low temperature plants came into ear while those grown at higher temperatures (15° - 20°C .) remained in the tillering stage. Conversely in the earliest sowings of all, in December or January, the temperature of growing had no influence on the time of earing.

This influence of temperature was not observed in the experiments with rye.

The factor influencing the earing in the different sowings is considered to be length of day and in the case of winter wheat the two factors light and temperature are thought to be complementary in determining the date of heading.

Lebedinceva 20.

Light plus temperature.

The experiments of the author made at the Physiological Department of the Institute of Plant Industry in 1929 were intended to investigate the influence of length of day on the earing of winter plants grown at high temperature, and to compare the influence of light ('photo-factor') with the effect of temperature (the 'thermo-factor'). The experiments were made with a "very winter" wheat, *Triticum vulgare* var. *lutescens* 329, and a "slightly winter" wheat, Kooperatorka, which were grown in boxes of five plants each, with two replications.

To investigate the first problem seeds previously sprouted at 15° - 20°C . were sown at four different dates, so that the plants were grown in different lengths of day, from 7 hours upwards. Thus the first developmental phase, from seedling emergence to shooting, was passed in the first sowing (Jan. 26) on an average in a 9-hour day, in the second sowing (Feb. 14) in an 11-hour day, in the third sowing (Feb. 28) in a $12\frac{1}{2}$ -hour day, and in the fourth (Mar. 21) in a 14-hour day. In addition, the plants were grown under continuous illumination. After sowing until the end of the experiments the plants were grown either in a heated greenhouse at a temperature of 13 - 18°C . or in a glass thermostat at a temperature of 20°C . In April, however, the temperature in the greenhouse during the day rose occasionally over 20°C .

To investigate the second problem, a part of the previously germinated seeds was chilled at a temperature of 0°C . before sowing; some seeds were so treated for two

weeks and some for a month and then sown simultaneously with the unchilled control seeds of the former experiment. Only in the first sowing (Jan. 26) were chilled seeds not used, while in the second sowing (Feb. 14) only seeds chilled for two weeks were added. Care was taken to ensure that chilled and unchilled seeds were sown at the same stage of sprouting.

The results are summarized in Tables 4, 5 and 6. The first table, relating to the influence of the photo-factor on earing of winter plants grown from unchilled seeds at relatively high after-sowing temperature, confirms the views of Maximov and Pojarkova that if sown sufficiently early winter wheats will come into ear without previous chilling; even *Lutescens* came into ear in the 20°C. series in the first two sowings. The length of time from sowing to earing moreover increases with the lateness of sowing, being for Kooperatorka 97 days in the January sowing and rising

Table 4.

Sowing	After sowing conditions.	Temperature	Kooperatorka.			Lutescens 329		
			13 - 18°C.		20°	13 - 18°C.		20°
		Length of day.	Normal day.	Pro-longed day.	Normal day.	Normal day.	Pro-longed day.	Normal day.
1			97	102	120	111	129	160
2			107	113	130	119	133	177
3			116	118	156	139	140	—
4			118	118	189	147	147	—

to 118 days in the last sowing. For *Lutescens* the period was more than a month longer in the March than in the January sowing. This effect is more marked at the high temperature; in addition to the fact that at each date the 20° sowing eared later than the 15° sowing, the interval between sowing and earing for Kooperatorka was over two months longer in the March than in the January sowing.

The results shew therefore that the length of the vegetative period is the result of the interaction of the temperature at which they are grown and the length of day, low temperature and short day accelerating ear emergence and high temperature and long day retarding it; and that the effect is more pronounced in the winter wheat than in Kooperatorka. The variants grown under continuous day fully confirm this, for all the plants grown at 13-18°C. under continuous day retarded their earing as compared with the same plants grown under a natural seasonal day. The effect is seen only in the first two sowings, since in the other two the natural day was so long as to be very little different.

The summary of the effect of the light factor on the plants chilled prior to sowing given in Table 5 shews that chilling accelerated the onset of earing in all variants, and that this effect was more pronounced in the periods of chilling of longer duration. It could be seen that, in spite of the stronger effect of chilling upon *Lutescens*, the earing of the latter was in all corresponding variants later than in Kooperatorka, the chilling being obviously insufficient for this strongly "winter" wheat. Apart from this, the effect of chilling was increasingly marked with progressively later sowing date. The somewhat contradictory effect of the fortnight's

Table 5.

Kooperatorka.							
Duration of chilling.		Unchilled.		Fortnight chilling.		Month chilling.	
Sowing.	After sowing conditions.	13-18°C.		13-18°C.		13-18°C.	
		Normal day.	Prolonged day	Normal day.	Prolonged day	Normal day	Prolonged day
2		107	113	97	84	—	—
3		116	118	116	98	81	61
4		118	118	93	93	69	62

Lutescens 329.

Duration of chilling		Unchilled.		Fortnight chilling.		Month chilling.	
Sowing.	After sowing conditions.	13-18°C.		13-18°C.		13-18°C.	
		Normal day	Prolonged day	Normal day	Prolonged day	Normal day	Prolonged day
2		113	133	104	97	—	—
3		139	140	129	111	102	87
4		147	147	124	124	96	92

chilling in the third sowing (Feb. 28), which retarded earing both in Kooperatorka and Lutescens as compared with the previous sowings, is thought to be traceable to some slight difference in the chilling conditions. It will be seen from the figures in Table 5 that the greatest reduction of time to ear emergence of chilled plants as compared with appropriate controls is obtained in the latest sowings, i.e. with the increased length of day. The variants grown under continuous day fully confirm this; Kooperatorka chilled for a month and sown on Feb. 28 came into ear when grown under natural seasonal day in 81 days and under continuous day in 61 days. Lutescens eared under the natural day in 102 days and under the continuous day in 87 days. The effect of prolongation of the day vanishes at the fourth sowing, as the natural day in April is already very long.

Since, as shewn in the former experiment, the earing of plants from unchilled seeds was retarded with the prolongation of the day, it can be concluded that pre-sowing chilling not only accelerates earing of winter plants, but also reverses the effect of day length, namely, the length of day becomes itself an accelerating factor.

As regards the significance of temperature on plants previously chilled, Table 6 shews that high temperature also retards earing after chilling, but its retarding effect decreases with increasing duration of chilling. It is possible that the duration of chilling was insufficient for variants subsequently grown at high temperatures.

Table 6.

Kooperatorka grown after sowing at a temperature of 20°C. in normal day.

Sowing	Duration of chilling.	Unchilled.	Chil'ed for a fortnight.	Chilled for a month.
2		130	105	—
3		156	153	112
4		180	135	91

Earing was more retarded in the later sowings and in the more "winter" wheats. It could therefore be expected that by still later sowings a date could be found which would be critical for the earing of winter wheats, as has been found by Lysenko and many other investigators.

Lysenko explains the failure of winter cereals to ear when sown after a certain date by the unsuitably high temperatures obtaining in the later sowings. That temperature alone is not the governing factor is shewn by the fact that Kooperatorka comes into ear at all when grown at 20°C. in the present experiments, not to mention the more winter variety *Lutescens* 329. Again, the temperature in the thermostat remained constant yet *Lutescens* 329 eared only in the first two sowings and the earing period for Kooperatorka became longer as the sowings became later; here the increasing length of day was the only factor that could be responsible and this is borne out by the plants grown in continuous light, other conditions being identical, in which the earing was retarded in the early sowings but unchanged in the late sowings where the natural day was so long that it itself exerted a retarding influence on the earing. Just as the temperature factor described by Lysenko, the photoperiodic factor is two-fold in its action, long day retarding ear formation in ordinary sowing material but accelerating it when applied to material receiving a pre-sowing treatment by chilling.

The author concludes that the stage from germination to shooting of the ear, which Lysenko divides into two phases, the first requiring low temperature and the second being favoured by high temperatures, is also the stage most sensitive to temperature and light and is divisible into two phases, the first being retarded by long day and the second accelerated by it.

The behaviour of winter cereals when sown in spring is explained by these relations to day length and temperature, the change from the vegetative to the reproductive state requiring low temperature and short day, whilst all remaining phases require the reverse of these conditions. If winter cereals are sown sufficiently early in spring the short day and low temperature are supplied during early development and later development takes place under the more favourable conditions of light and temperature.

The experiments with continuous light have shewn that long day has an accelerating effect when combined with chilling in the first stage. The conclusion that short day, like pre-sowing chilling, accelerates the first phase, is arrived at indirectly as a result of the present experiments. Experiments to test this directly have been made by Oleinikova (cf. p. 32). It can be seen also in the results of Adams (1924). (See Purvis p. 115).

The general conclusion reached by the author with regard to the division of plants into long and short-day types is that whereas spring wheat and rye are long-day plants, winter wheats can be ascribed to the long-day group only conditionally, namely, they behave as long-day plants only after vernalization.

Oleĭnikova 24.**Variations in length of day.**

To ascertain the influence of the length of day on plant development and eventually on the time of earing, a trial was made by the author in 1930 with winter wheat varieties, Kooperatorka and Lutescens 329.

Seeds were divided into two lots, one of which was subjected to a pre-sowing chilling at a temperature about 0°C for 12 days and the other was not. After sowing (May 17th) each lot was divided into three groups :

- (1) under a long (18 hour) day which was gradually shortened (by 30 minutes every 5 days) to a short 9-hour day ;
- (2) under the reverse conditions of gradually increasing duration of daylight ;
- (3) under the natural seasonal day of Leningrad.

Change in length of day was made at the expense of the evening and morning hours. The thermal conditions after sowing until the end of the experiment were such that up to July 6th there were only 8 days with temperatures which could favour further vernalization of the plants. On September 3rd all plants were removed to a heated greenhouse where the temperature was never below +15°C.

Seedlings of chilled and unchilled seeds appeared on May 24th and 23rd respectively. Even at the tillering stage (June 4th) a sharp difference was found between the first and the second groups, namely, the tillering of the second group (short day) was prostrate and typical of winter forms, whereas the character of the tillering of the first group (long day) was erect and resembled that of the spring type. The plants of the second group were at first somewhat smaller, but later with the increase of day length they soon overtook those of the first group. Only plants of the second group came into ear ; both variants of Kooperatorka eared almost simultaneously, the chilled variant being one or two days later, whereas earing of both chilled and unchilled Lutescens 329 occurred on the 164th and 172nd days respectively. Neither the first nor the third group formed rudimentary ears until the end of the experiment. This behaviour of chilled and unchilled variants is explained by the fact that 12 days' chilling was insufficient ; thus Kooperatorka, according to Lysenko, must be chilled for 30-40 days in order to complete the thermo-stage.

Since the growth of all experimental plants progressed under conditions similar in all respects except in length of day, the results led the author to the conclusion that the increase of the light duration towards the end of the vegetative season, as opposed to the decrease, is favourable for the transition of the plants to reproduction.

Vasiljev 29.**Light plus temperature.**

Experiments were performed at the Institute of Grain Husbandry, Saratov, on varieties of winter wheat. Unvernalized seed was sown in pots on Nov. 5 and germinated Nov. 17. The pots were divided into the following series :

- (1) 45 days at 8 - 10°C. under natural light (7 - 8 hrs.) then transferred to continuous light (100 M.K.) at 20 - 25°C.
- (2) 15 days at 8 - 10°C. with 7 - 8 hrs. light, then continuous light at 20 - 25°C.
- (3) 45 days at 20 - 25°C. with 9 hrs. light then continuous light.
- (4) Continuous light at 20 - 25°C.

Control vernalized seed (0 - 2°C. for 60 days, then as Series 4).

The results are shewn in the Table.

Table 7.

Variety.	Series 1.		Series 2.		Series 3.		Series 4.		Control.
	Number of days from sowing to								
	begin- ning of earring.	50 per cent earring.	begin- ning of earring.	50 per cent earring.	begin- ning of earring.	50 per cent earring.	begin- ning of earring.	50 per cent earring.	begin- ning of earring.
Kooperatorka ..	97	97	92	97	112	115	133	154	54
Wheat rye hy- brids 27/36 ..	97	97	94	100	105	112	135	154	54
Moskovskaja ..	102	107	122	130	107	113	144	160	—
Erythro- spermum 118	100	101	95	132	100	110	129	154	54
Lutescens 121 ..	104	110	107	128	122	128	154	—	58
Lutescens 329*..	102	106	106	132	106	115	—	—	58

*Lutescens 329 had not eared in Series 4 at the time of writing the paper.

The following results appear :

- (1) All the series came into ear, even series 4, although the conditions of growth were well outside the limits stated by Lysenko as obligatory for ear formation (cf. Čailahjan).
- (2) Earing was delayed however in series 2 and 3 and more so still in continuous light.
- (3) Vernalized seed shewed an acceleration in earing in all varieties.

Although the vernalized seeds attained ear emergence in a shorter time than any of the untreated seeds this is true only if the time elapsing from germination is counted. If the time of vernalization itself is included then the actual number of days required to ear is not less than in Series 1. This can be seen by adding 45 days (the minimum time for vernalizing winter wheat) to the figures in the control column.

The author concludes from these experiments that the conditions described by Lysenko as obligatory for the earing of winter cereals are not the only conditions under which this occurs, and indeed the conditions described by Lysenko are not even those which bring about earing in the minimum time.

C.—LIGHT.

Čailahjan 8 and 10.

Vernalization by light.

In experiments to test Gassner's conclusions, Murinov obtained earing in rye and wheat without low temperature when sowing was done sufficiently early. Maximov and Pojarkova and many others have made the same observation and further shewn that earing in late sowings is also independent of the action of low temperature. Lysenko's theory of vernalization, valuable as it is from the practical standpoint, fails to provide an adequate explanation of these discrepancies, the key to which is contained in the work on photoperiodism. A very full review of the literature on this aspect is given by Čailahjan, who has undertaken a further investigation on these lines,

The experiments were made on the following winter varieties: "Vjatka" rye, "Ukrainka" wheat (*v. erythrospermum*), barley 02495 (*pallidum*), Ukrainian vetch (*Vicia villosa*) No. 101, Ukrainian rape (*Brassica napus v. oleifera*) A-155; and the spring varieties: wheat, "*erythrospermum* 0341", barley "Krymskii 016", Ukrainian vetch No. 201 and Ukrainian rape A-59.

The experiments were carried out in June, after the critical sowing date for obtaining earing in winter cereals in Leningrad and at a time when no natural vernalization by low temperature would be possible. Experimental plants were subjected to artificially controlled day lengths of 10 and 24 hours and to normal day length; at a later date some of the variants which had received long day in the early stages were transferred to short day and vice versa; others were retained in the same conditions throughout the experiment. The behaviour of the plants at different stages of the experiment is described in detail and illustrated. In the longer days the greater degree of advancement of the spring forms was very evident, the difference being much less in the short day treatments, where the spring forms had assumed a more or less winter habit. Both spring and winter forms were distinguished by a higher chlorophyll content in the short than in the long days. The spring forms, however, when transferred to the longer day, immediately progressed towards flowering, a property not shared by the winter forms. The latter when transferred to long day were influenced gradually and the behaviour of the different plants shewed that the tillering or branching habit of winter plants approaches more and more to that of spring plants in direct proportion to the daily period of illumination.

Winter rye came into ear in the continuous light treatment in 64 days from sowing, in the normal day followed by continuous light in 72 days and in the 10 hour followed by 24 hour day in 86 days. All other treatments failed to ear. In view of the temperature conditions it is concluded that vernalization had been effected by the light alone. The condition of the ear primordia was examined and was found to correspond to the external habit and earing behaviour of the different variants. The most advanced primordia were found in the treatment receiving first 10 then 24 hours, followed by the normal day treatment. At this point there was a sharp demarcation, for all other treatments had quite small ear primordia which were not apparently developing. Winter barley behaved similarly, but the response was slower and less pronounced. In particular the marked response of the ear primordia was lacking and it is concluded that this lags behind the physiological processes leading to development and also behind the change in habit associated therewith. The response of the winter wheat was still less marked and it is concluded that the vernalization of winter barley and winter wheat by light is extremely slow. Indeed the varieties were not fully vernalized during the total period of the experiment. The plants receiving continuous light, and normal day followed by continuous light were however definitely more advanced towards reproduction as shewn by the fact that they passed to the stooling stage, acquired a more spring type of habit and a somewhat greater development of their growing points.

The light vernalization is thus seen to be most rapid when the continuous light is applied from the time of seedling emergence and is somewhat slower when it is applied only at the tillering stage, though however long the plants had been in short day they began shooting when transferred to continuous light. The preliminary light treatment also influences the later behaviour since those plants which before the application of continuous light received normal daylight eared earlier than those receiving a 10 hour day before treatment.

Winter vetch was also vernalized by continuous light, since plants in continuous light and those transferred to continuous light from a normal day bore flowers and fruit and made much more vigorous vegetative growth than the remaining treat-

ments, which did not flower at all. The response of winter rape to continuous light consisted in the formation of rudimentary inflorescences with reduced stems, while the plants in all other treatments remained in the typical rosette stage.

Spring varieties of wheat, barley, vetch and rape were very much retarded in reproduction when grown in a 10 hour day, under which they assumed the typical habit of winter plants sown in spring. Reproduction began immediately when they were transferred to long day, in which case they developed into vigorous plants and exceeded the long-day plants both in dry weight and height. This increase in size was manifested both in a greater length and greater number of internodes.

These experiments leave no doubt that the habits characteristic of winter and spring forms respectively can be entirely reversed by appropriate light treatment and photographs are presented in illustration of this.

The chief factors in the conversion of winter varieties into spring varieties are temperature and light. These, always acting in conjunction with a complex of other factors, are complementary in action—in one set of conditions the temperature is the decisive factor, while in another the light, represented by continuous light or suitable photoperiods, is the decisive factor. Thus the nature of a variety can best be determined by the critical sowing dates in a given region, i.e. by its response to the complex of environmental factors and not to temperature and light considered separately.

The division of plants into spring and winter varieties is quite arbitrary and in reality an unbroken series exists between the extremes of the one type and the extremes of the other. This viewpoint is substantiated by the above experiments and is further confirmed by the examination of the growing point of winter rye under different light conditions, where a gradual increase in differentiation of the ear is observed as vernalization by light progresses.

The differences between spring and winter forms are in all probability connected with the evolution of the forms as they migrated from equatorial towards more and more polar zones and the degree of differentiation in the forms existing at present increases progressively towards the poles, parallel with the increase in extremes of temperature and light duration. Similarly the amount of vernalization required by any given variety is not a fixed quantity, but varies with the temperature and light conditions of the country in which the variety is to be grown.

The real difference between spring and winter varieties is physiological in nature and can be modified only by prolonged action of the particular factor. It is therefore obvious that attempts to effect vernalization by removal of some inhibiting or retarding factor are in principle erroneous, and it is not surprising to find that the experiments with various stimulative factors undertaken to this end have resulted in failure.

A possible exception is the experiment of Dorošenko (14) in which winter rape treated by X-rays displayed a more vigorous vegetative growth and produced a flowering stem whilst control plants remained in the rosette stage. However, this is probably not a case of a physiological influence, but of a "spring" mutant.

Razumov 26.

Quality of light.

Experiments to test the effect of replacing the dark period by light of various colours were made according to the following simplified scheme:

- (a) 17 to 18 hours daylight plus 7 or 6 hours darkness;
- (b) 12 hours daylight plus *either* 12 hours monochromatic light (red, yellow or blue) *or* 12 hours darkness.

In *Avena sativa* ssp. *diffusa* No. 909 from Finland, low intensity red or yellow light had an equivalent effect to sunlight in accelerating earing, whereas blue light

of the same intensity had a similar effect on reproduction to that produced by darkness, and an effect on growth similar to that produced by light. Millet shewed no difference in earing under red, yellow, or blue light or darkness, but the additional illumination produced the formation of more dry matter and a larger grain yield.

Another experiment was made simultaneously with the same oats and *Ullucus tuberosus* to investigate the influence of (1) higher intensities of the additional illumination, and of (2) green light upon reproduction. The following are the conclusions: (1) the replacing of darkness with the violet-blue-green section of the spectrum of intensities up to 25 per cent of full sunlight acts as darkness on reproduction of oats and tuber formation of *U. tuberosus*; (2) an increase of red rays even of low intensity greatly accelerates the rate of reproduction.

A third experiment had the following objects: (1) determination of the absolute magnitude of intensity capable of influencing reproduction; (2) the possibility of producing an effect similar to that of long-wave rays by increasing the intensity of the blue-green light; (3) verification of the results of the first two experiments with particular reference to short-day plants.

Accordingly the experiment was made in the following manner:

- (a) 17 to 18.5 hours daylight plus 7 or 6.5 hours darkness.
- (b) 10 hours daylight plus *either* 14 hours monochromatic light of varying intensity and colour *or* darkness.
- (c) 10 hours daylight plus 7 hours monochromatic light plus 7 hours darkness.
- (d) 10 hours daylight plus 14 hours darkness.

Thirteen varieties of long-day plants and ten of short-day plants were used in this experiment. Owing to the wide scope and large scale of the trials, it is impossible to deal with the results for each plant separately. Some data are, however, summarized in Tables 8 and 9.

The following conclusions have been made as regards long-day plants:

- (1) additional red light even of very low intensity accelerates reproduction, while even very high intensities of blue light produce an effect similar to darkness or only a slight acceleration;
- (2) reproduction is retarded by an increase in the blue rays or a reduction in red rays;
- (3) different species and varieties of various geographical origin vary in their response to the quality of light;
- (4) although most examples shewed largest seed yield under red light, southern forms also produced a considerable yield under blue-green light;
- (5) for all long-day cereals additional red light produces earlier earing and maximum seed yield;
- (6) the greatest height was also obtained under red light.

The following conclusions are made for short day plants:

- (1) additional short-wave light influences reproduction in the same way as darkness, i.e. simultaneous earing or even earlier as in maize; although additional long-wave illumination does not inhibit reproduction, it retards its progress;
- (2) an ever-increasing retardation is produced in reproduction by increasing the long-wave rays, even at intensities lower than the blue green rays;
- (3) although these conclusions hold true in general, each variety or species shews an individual response to additional illumination;
- (4) plants which have received the additional illumination have a shorter vegetative period but shew a considerable increase in their vegetative mass and seed yield.

Table 8. Response of long-day plants to different light treatments.

Number.	Light treatment.		Oats (<i>Avena sativa</i>) 114 days.*												Beans (<i>Phaseolus</i> sp.) 87* days.			Poppy (<i>Papaver</i> sp.) 83 days.*						
	Duration of Light.	Wave length.	Abyssinia.			Palestine.			Asia Minor.			Shatilov.			Norway.			Flowering.	Height.	Weight for fruit.				
			Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.							
1.	Long day 18 hrs. 720-540 720-540 660-400 640-400 570-400 570-400 Short day 10 hours.	800-290	45	69	1.62	33	30	0.50	41	60	1.44	45	72	0.83	42	66	1.20	34	79	4.21	40	67	1.19	
2.		720-540	46	69	1.80	28	46	1.09	46	72	2.43	44	81	1.38	42	71	2.86	34	68	4.18	53	66	0.6	
3.		720-540	44	77	1.04	40	38	2.37	60	85	1.72	68	72	1.08	64	42	0.36	34	62	2.81	—	25	—	
4.		660-400	13	51	76	4.22	45	38	1.59	54	89	3.20	68	69	0.73	109	41	0.22	33	63	1.78	—	22	—
5.		640-400	18	54	68	0.79	50	33	1.41	69	53	0.80	101	33	0.09	—	24	—	32	29	1.60	—	22	—
6.		570-400	85	53	63	1.85	50	34	1.77	68	84	1.80	—	35	—	—	20	—	31	23	1.09	—	33	—
7.		570-400	21	51	82	1.33	51	37	1.45	70	65	0.62	—	31	—	—	20	—	31	20	1.73	—	23	—
8.	—	—	60	44	0.05	49	45	1.07	85	66	0.26	—	26	—	—	21	—	—	19	—	—	21	—	

Note. The height of the plant was measured at the time of harvest.

Earing indicates the number of days from germination to ear emergence.

The weight of fruit indicates the dry weight of the fruit in grammes.

* Duration of experiment.

Table 9. Response of short-day plants to different light treatments.

Number.	Light treatment.		Millet (<i>Panicum miliaceum</i>).												Soybean (<i>Glycine Soja</i>).			Beans (<i>Phaseolus</i> sp.).			Potato (<i>Solanum tuberosum</i>).		
	Duration of Light.	Wave length.	Tulun.			Toidem.			Mongolian.			Afghan.			Minsk.			Mexico.			Wohltmann.		
			Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of fruit.	Earing.	Height.	Weight of tubers.
1.	Long day 18 hrs.	800-290	51	81	0.38	53	87	0.63	61	72	0.41	87	72	0.80	—	67	—	—	50	—	40	71	14
2.	10 hours of daylight + 14 hours of additional light.	720-540	29	51	0.96	42	74	1.55	47	98	2.01	53	78	3.56	62	56	0.67	—	98	—	—	76	36.8
3.		720-540	3	27	0.50	36	49	2.03	42	101	9.26	50	74	2.91	58	41	1.24	32	72	3.58	—	54	21.3
4.		660-400	13	27	0.86	40	39	1.42	42	104	2.73	50	70	3.36	43	31	2.09	—	85	—	—	44	55
5.		640-400	18	24	0.47	33	20	0.62	26	68	2.15	47	67	5.75	46	29	2.39	44	33	3.17	—	24	7.27
6.	10 hours of daylight + 14 hours of additional light.	570-400	25	29	0.56	32	45	3.55	27	66	2.79	50	83	3.69	44	24	2.13	44	27	6.47	—	21	95
7.		570-400	21	23	0.60	29	39	1.50	25	54	2.95	41	72	4.15	44	25	2.51	44	41	7.45	—	20	96
8.	Short-day 40 hrs.	—	23	24	0.58	30	32	0.39	27	41	1.16	41	27	2.25	43	20	1.54	42	25	6.03	—	27	90

Comparing the results obtained with the contemporary form of Lysenko's hypothesis, the author states that the progress of the second stage is governed not merely by the presence or absence of light, but of the red section of the spectrum which even at low intensities can influence the progress of this stage when acting for a sufficiently long period. Lysenko claims that for the first stage the temperature factor (duration and intensity) in combination with other factors can be very accurately prescribed; Razumov states that the same approach should be made in the second stage to the photo-factor, meaning thereby not merely light or darkness, but specifying it by its physical magnitude (wave-length and intensity).

The results obtained should be ascribed to the directing influence of light upon the character and rate of the physiological process in plants and not upon assimilation. Very weak light of no photosynthetic value can produce radical changes in the physiology of the plant. Since the influence of light can be independent of assimilation, these conclusions may possibly be applicable to slightly sprouted seeds.

With particular reference to the application of photoperiods to experimental work and breeding, the author emphasizes (1) that normal plants with a high seed yield and short vegetative period may be produced by treatment with 10 hours' daylight plus 14 hours' additional monochromatic light of low intensity properly selected for the species and variety in question, and (2) that treatment with various additional illuminations may affect certain physiological processes such as increased forage and seed yield, rapid tuber formation, etc., in the desired direction.

Çailahjan 9.

Sensitive periods. Short-day plants.

The author has investigated the effects of short day exposure (10 hours) and continuous light for a period of 7 days at different times in the life history. The experiments were conducted in pot cultures with millet, *Panicum miliaceum* v. *effusum* (Saratov Exp. Station), during the summer of 1933 in a greenhouse of the Leningrad Institute of Textile Crops. Eight series of plants were used covering a total period of 56 days (June 10 - August 5). The control plants were exposed all through to normal long days (17-18 hours). The experiment was completed on August 31.

The effect of continuous light was quite inappreciable. The sensitivity of the plants to the effect of 7 days exposure to 10 hour days varied with the stage of the plant, though the effect only became apparent at the stage of panicle formation.

Two stages of high sensitivity were noted; the first at germination (7-14 days), and a second at the age of one month (28-35 days). Sensitivity then decreases again. Growth analysis shewed that the second sensitive period coincides with the time of maximum growth rate of the control plants. A lesser accumulation of dry matter relative to the control plants was found in the series referred to above. The series exposed early to short days produced fewer internodes, but shewed a great acceleration in the phase of formation of panicles. The series exposed at one month old (28 - 35 days) shewed a great retardation of growth of the main axis as well as the laterals, which led to some days delay in the opening of the panicle.

Litvinov 22.

Localization of effect.

Lysenko's statement that all changes occurring during the developmental stages of the plant occur only in the cells of the growing point is of great importance for the theory of vernalization and the present study has been made to test it experimentally and to determine whether the complex of external conditions concerned acts directly on the cells of the growing point or acts on the whole plant, which then emits some internal influence that exerts its effect on the cells of the growing point.

The growing point of young soya bean seedlings was darkened by placing caps over them from the moment of germination, leaving the rest of the plant exposed

to the long day of Moscow and free to carry on assimilation. A variety known to react markedly to vernalization was chosen for the experiments. One experimental plant was grown in each of 6 pots, together with one control plant without the caps on the growing point. The caps were made of plastic paraffin coloured black and were quite opaque. With the development of each set of leaves the caps were removed to allow the internodes and the young leaves, which were quite etiolated, to extend, after which the caps were replaced. Caps were also placed on the growing points of the axillary buds. The last three leaves unfolded without an interval of waiting so that for the last three periods, 9 days in all, the growing point was in uninterrupted darkness; thus during the whole period of the experiment, 28 days in all, the growing points received 492 hours of darkness, including the 60 hours of night (which is equivalent to 41 twelve-hour days) and 180 hours of light. During the same period the controls and the illuminated parts of the experimental plants had received 168 hours darkness and 504 hours light. The variety used was known to require only 320 hours of darkness, when treated with an 8 hour day, in order to flower normally, so that the controls had received one third the sum of darkness received by the experimental plants and half that required for flowering. On this basis they were expected to flower only about the 3rd August, and actual flowering began between August 1 and 3. The experimental plants all flowered about the same time also, between 31st July and 3rd August and the further development of the experimental and control plants shewed no differences, though the yield of the experimental plants was slightly less.

The conclusion is therefore reached that the changes occurring during vernalization do not occur in the growing point in response to the direct action of the external conditions, but must occur in the whole plant; being probably of a chemical nature these must in turn effect a specific change in the cells of the growing point. (See Ljubimenko, p. 18.)

The growth of the terminal bud was slightly stimulated by the action of darkness, whilst that of the lateral was retarded.

Konstantinov 19.

Reversibility of effect.

Experiments were made at Tashkent in which cotton plants were subjected to daily periods of illumination of 6, 9 and 12 hours, with a control receiving normal daylight of an average duration of about 14 hours. Observations were made on the plants at all developmental stages, leading to the conclusion that cotton is a short-day plant in the accepted sense, since a reduction of the daily period of illumination occasions an earlier maturity. Different varieties react differently however, the late perennial forms giving the most pronounced effect as a rule, while the early and ultra-early forms do not react at all; some of the perennial forms also do not react. The optimum period of illumination is also different for different forms, varying between 8 and 12 hours daily.

The reaction of the plant to reduced length of day is to produce sympodial branches at a lower level and so form flower buds and bolls at an earlier date. The habit of the plant and the form of the vegetative organs is often also altered. When this change has been produced the plant proceeds to flower and form fruit even if grown for the rest of the time in a long day, and thus the effect is regarded as a true photoperiodic induction. The minimum length of time required to produce the after-effect remains a matter of doubt, for plants of *G. peruvianum* were grown for one and a half months under conditions of short day and began to form flower buds, but on transferring to long day again assumed the perennial habit. The period of treatment required varies with the different species and varieties, one and a half months being obviously insufficient for *G. peruvianum*. The reversal of the behaviour of the above-mentioned plant however shews that Lysenko's view of the

tissue changes occurring at the point of formation of the first sympodial branch is too simple, for on his hypothesis tissue which has once undergone the changes preparatory to reproduction can never be reversed. (See Ljubimenko, p. 18.)

Čailahjan and Aleksandrovskaja 11.

Photoperiodic after-effect.

Recent investigations (Krapivina, Razumov, Ljubimenko and Ščeglova) have shewn that the photoperiodic after-effect established by Eghis is as important in short-day plants as in long-day plants. Dolgušin, however, denied the after-effect of a long day on millet if this plant is later grown under a shortened day. Experiments made by Čailahjan on the effect of a short day on millet have shewn that this plant is particularly sensitive to photoperiodic induction at early stages and during the period of maximum growth, whereas under the conditions of the experiment no after-effect of long-day induction on millet development was observed.

In order to ascertain whether there exists a photoperiodic after-effect of long days on short-day plants, and of short-days on long day plants an experiment was made with a Saratov millet (typical short-day plant) and a spring barley (Krymskii 016, a long-day plant). Seeds were sown on May 23, 1934, in pots and grown until the emergence of seedlings in 2 series, one under a short 10 hour day (from 8 a.m. to 6 p.m.) and the other under a normal day. On every sixth day after the seedlings had appeared 2 pots of barley and millet were transferred from the normal day to the shortened day and similarly 2 pots were removed from a short day to a normal day. In 6 days these pots were returned to their previous conditions and the next pairs were moved. Thus by the end of the experiment there were short-day variants which had received 6 days exposure to a normal day at various ages, and similarly there were normal-day variants which had received a short day for 6 days. The control pots were kept under a short day or a normal day throughout.

Millet. The short-day variants of millet did not shew any conspicuous differences as a result of exposure to a long day for 6 days and differed little from the control, the delay in the time of emergence of panicle not exceeding 6 days. On the other hand the long-day variants showed a clear response to their 6 days' exposure to short-day, an acceleration in panicle emergence from 2-16 days being observed.

Barley. The long-day variants of barley showed practically no response to exposure to the short-day for 6 days; with the exception of the first pair which was delayed by 6 days all variants emerged simultaneously with the control. The short day variants showed a clear response to exposure for 6 days to a long day. The first 3 pairs which were under a normal day in the early stages of their growth developed stems before any other variants or the control, the difference ranging from 2-34 days. Comparing the response of the short-day and long-day series of long-day plants, it can be seen that the effect of the normal day in the short-day series considerably exceeded the duration of treatment, whereas in the long-day series the differences between variants are within the duration of the treatment with short-day. A reverse relation is found in the case of millet.

The experiment, therefore, shews that for short-day plants there is a photoperiodic after-effect but only from the short day and vice versa for long-day plants, thus confirming the conclusions of Dolgušin. In other words, the photoperiodic after-effect (induction) is observed only in cases where the factor operating in induction normally accelerates development and reproduction.

D.—LIGHT AND OTHER FACTORS.

Pivnoskii.

External factors and phasic development.

The author, who disagrees with Lysenko's distinction between growth and development, undertook the investigation of the effects of the so-called "unipolar

changes " in external factors at definite periods of development, i.e. treatment with one extreme or the other of the various factors. The experiments described, which were conducted at Gory-Gorki in 1929-1932, may be summarized under the three following headings:

- (1) Effect of short days.
- (2) Effect of drought.
- (3) Effect of nitrogen and phosphorus starvation.

The method employed was uniform throughout. The plants were grown in pot culture in sifted garden soil, maintained at a constant humidity of 60 per cent saturation. The treatment under investigation was given for periods of 15 days at varying times in the life cycle, both before and after treatment the plants being kept under normal conditions.

Soya beans were exposed to shortened day length at seven different stages in parallel experiments, each exposure being of 15 days. The results for one experiment are shewn in Table 10.

Table 10.

Data recorded.	Control.	Short-day period.						
		June 1st— June 15th.	June 16th— June 30th.	July 1st— July 15th.	July 16th— July 30th.	July 31st— Aug. 14th.	Aug. 15th— Aug. 29th.	Aug. 30th— Sept. 13th.
Number of days from sowing to flowering ..	58	41	85	48	58	58	58	58
Average length of stem in cm. ..	117	90	43	110	113	125	126	130
Average number of pods on a plant	14	12	1	14	15	15	14	13
Average number of seeds from one plant ..	24	17	1	25	27	27	25	23
Average seed yield in grm. from 4 plants ..	18.0	14.6	0.5	18.7	21.1	19.8	16.3	13.4
Average straw yield in grm. from 4 plants ..	38.2	32.7	24.4	24.4	39.9	33.8	41.9	44.7

The following effects are seen: (a) Short days from June 1-15 (cotyledon stage) reduced the time to flowering from 58 to 41 days, the exposure June 16-30 (1-5th leaf) increased the time from 58 to 85 days, while exposure July 1-15 (6 and 7th leaf) again reduced the time to flower. (b) Vegetative growth as indicated by stem length was reduced somewhat by the first exposure, much more so by the second, while subsequent exposure had little effect. Similar results appear for number of pods and number and yield of seed per plant.

The second experiment gave somewhat similar results. Two experiments were also performed with barley in 1930 and 1931. Again seven exposures were given. The results of one experiment are given in Table 11.

Table 11.

Data recorded.	Control.	Short-day period.						
		June 6th— June 20th.	June 21st— July 5th.	July 6th— July 20th.	July 21st— Aug. 4th.	Aug. 5th— Aug. 19th.	Aug. 20th— Sept. 3rd.	Sept. 4th— Sept. 18th.
Number of days from sowing to earing	39	38	57	42	39	39	39	39
Average height of plant in cm.	100	105	91	76	89	98	97	96
Average number of grains on one plant	27	27	17	2	20	30	23	25
Average grain yield from 15 plants	10.4	9.8	4.8	0.4	6.4	10.8	9.5	10.7
Average straw yield from 15 plants	14.4	16.8	15.9	14.3	12.0	15.0	13.9	14.1

Exposure at the first stage June 6-20 (pre-tillering) has somewhat increased the height of the plant and the straw yield. The second exposure June 21-July 5 leads to increase in time to ear, reduction in height and great reduction in yield of grain. The third exposure July 6-20 shews no great effect on ear emergence, but still greater reduction in height and yield: both these exposures coincided with the tillering period. Later exposures shewed increasingly small effects as compared with the control plants.

Analogous experiments were performed on water shortage with barley, oats and white mustard. Adverse effects of drought were obtained only in the early stages both with cereals and mustard. Manurial experiments demonstrated the importance of nitrogen and phosphorus during tillering and shewed that yield is independent of the presence or absence of these nutrients after this stage.

Data are given from these experiments, leading to the conclusion that the plant develops in stages which require for their optimum progress different complexes in external conditions. The four stages, namely "Seedling Stage," (germination to appearance of 3rd leaf), "Tillering Stage," "Stage of Seed formation," and "Maturity" could be distinguished in the development of soya bean and barley, irrespective of the environmental factor that was changed. In order to obtain the greatest agricultural effect, plants at different stages of development must be given a different and strictly defined complex of environmental conditions. For example, plants at the "seedling stage" (particularly plants of southern origin) require a short day, and a relatively small amount of water, etc.; plants at the "tillering stage" on the contrary require a long day, a large amount of water, increased nitrogen and phosphates, etc.; plants at the "stage of seed formation" again require a short day, a smaller amount of water and little or no nitrogen or phosphorus, etc. For the "stage of maturity," however, the conditions studied in these experiments, such as light, water, and nitrogen and phosphorus are without influence upon

the rate of development ; it would, therefore, seem that plants at this stage acquire a new, as yet uninvestigated quality of an energetic nature.

The behaviour of the plants under the treatments described demonstrates the significance of the extreme limits (polarity) of the various factors upon plant development. For instance plants are seen to be equally in need of light and darkness, according to their period of development, or in other words at one period "continuous day" is needed and at another period the opposite extreme "continuous night." This illustrates the conventional nature of the classification of plants into long-day and short-day plants, plants resistant and non-resistant to drought, etc., whereas actually the same plant at certain stages of its development can be referred to one group of such a classification and at other stages to its diametric opposite. Thus for instance, soya beans at the seedling stage require a "short day" ("continuous night"), whereas at the stage of tillering the same soya bean behaves as a typical "long-day" plant. Again, oats are resistant to drought at a certain stage of development, but shew very little resistance during the remaining period. White mustard illustrates the converse case.

These considerations have a bearing on many of the common agricultural practices such as soil preparation (regulation of water and nutritive conditions), depths of seeding ("continuous night"), vernalization (pre-sowing completion of stages), mulching ("continuous night"), growing of seedlings in a greenhouse (light condition), illumination by electricity ("continuous day"), irrigation and surface manuring with readily soluble fertilizers (water and nutritive conditions), etc., the application of which with respect to the various developmental stages acquires a special meaning and significance.

This experiment also shewed that the process of plant development is characterized by changes of a qualitative nature (stages), by a transition from one stage into another of contrary factor requirements, and by an apparent repetition at the end of development (at the stage of seed setting) of the processes characteristic of the beginning of development. As the changes evidently occur in the growing point the branches of different orders are at different stages and must be viewed as distinct.

Voskresenskaja 30.

Flowering potato tubers.

In the spring of 1931 various wild potatoes and certain cultivated varieties on sprouting gave shoots which immediately formed flowers, when only a few inches in length. The wild potatoes had been stored during the winter at a temperature of $1-3^{\circ}\text{C}$. and were sprouted at a temperature of 12°C . For the first month they had been in covered boxes, the rest of the time they were in glass jars in full sunlight. When placed on wet filter paper in the greenhouse at $15-20^{\circ}\text{C}$. the flowering was more abundant and perfectly normal flowers were developed.

In June experiments were made with tubers of *Solanum tuberosum* maintained in suitably moist conditions (1) in the laboratory at 12°C . with natural illumination, (2) in the greenhouse with a mean daily temperature of 17°C . and more, in full sunlight, and in partial shade, (3) in the hothouse with a mean daily temperature of 28°C ., with abundant moisture and good illumination and (4) in boxes in a shed, in diffused light and at a temperature of $10-12^{\circ}\text{C}$. The tubers in the hothouse flowered rapidly, and those in the greenhouse three days later, both those with full light and shaded. In the shed, flower buds were formed on the early maturing varieties. Tubers kept in the laboratory formed no flowers at all, nor did others kept in closed desiccators.

Thus it seems that the main requirement for flower production is an abundant moisture content of the air and a temperature of $17-28^{\circ}\text{C}$.; light is at any rate not a main factor. In this way flowers were obtained from a number of cultivated

varieties and from *S. demissum* and *S. andigenum*. Further studies are being made to try and improve the technique of this important method of obtaining flowers direct from the tuber without the usual vegetative cycle.

E.—STIMULATIVE FACTORS.

Attempts have been made to produce results similar to those of vernalization by the use of various stimulative and other factors. Thus Istomina and Ostrovskii (17) working with ultra-sonic vibrations on potato tubers claim that the treatment influences both rate of development and tuber yield. Čiževskii (12) found that the negative ionization of seeds stimulates the energy of their sprouting, increases germination and, not infrequently, yield and, on the whole, raises the general ability of plants to overcome adverse environmental conditions. At the same time a shift in the iso-electric point was observed, comparable with that reported by Richter (see p. 49) on vernalization. The practical significance of such a method is considered to be great, as the forty-five days required for the completion of the first stage would be reduced to a few minutes.

Again various influences have been used by Kavcevič and Korzun (18) on dry seeds of tomatoes, who claim that ultra-violet rays, magnetic field, electric current and liquid air accelerated flower and fruit formation and frequently fruit yield, though the weight per fruit was often reduced. Ionization resulted in a delay in flowering and fruit formation and a reduction in fruit yield. The combined effect of phosphorus and length of day has been observed by Eidelman (15).

Godnev and Golitsynskii (16) investigated the influence of reducing and oxidizing agents on the vernalizing process. Winter and spring wheats were used, vernalized for 35 days at 22-5°C. The following reducing agents were tested: glucose, formaldehyde, pyrogallol, hydroquinone, ferrous sulphate, ferrous nitrate, acetylene, carbon monoxide and hydrogen sulphide. The oxidizing agents tested included potassium chlorate, ferric sulphate and potassium iodate. With the exception of pyrogallol, the substances tested had little or no influence on the time of earing. Pyrogallol accelerated the onset of earing by 5-7 days in vernalized wheat, whilst in unvernized wheat this effect did not occur.

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3.—BIOLOGICAL PROCESSES ASSOCIATED WITH PLANT DEVELOPMENT.

A.—DIAGNOSIS OF THE VERNALIZED STATE.

Bassarskaja 31 and 32.

Diagnosis by staining.

The investigation deals with physico-chemical changes of the protoplasm during development, in relation to the various phases postulated by Lysenko. Two methods were used :—

(1) Precipitation of Prussian blue in the tissues by addition of the requisite reagents. (Thermo-stage).

(2) Vital staining of cells with 0.01 per cent solutions of methylene blue and methyl violet. (Photo-stage).

1. Longitudinal sections of the embryo were prepared and mounted. The slides were then treated with 5 per cent ferric chloride for 2-3 minutes, rinsed in water, dried with filter paper and then treated with 5 per cent potassium ferrocyanide. Treated in this way, vernalized and unvernallized seed shewed differences in reaction : the growing point of the vernalized seeds stained intensely blue, whereas the unvernallized seed remained unstained or became yellow or green. The cells below the growing point stained an intense blue in both vernalized and unvernallized seeds.

It is claimed that as the seeds pass towards completion of the vernalizing process blue-stained cells appear scattered on the green background of the general tissue of the growing point.

The absence of Prussian blue in the cells of unvernallized seed may be interpreted in two ways : either the ferric chloride does not penetrate into the cells, or is reduced to ferrous chloride in the tissues. The latter suggestion is confirmed by the formation of Prussian blue on addition of potassium ferrocyanide. The author therefore considers it possible that vernalization produces a change in the oxidation-reduction potential of the cells.

Studying winter and spring wheats by the above method, a sudden change was observed in reaction after the seeds had been vernalized for a definite period. Seeds were vernalized in successive stages, being dried down in the intervals and only on completion of the total vernalization period were the colour changes observed. Similar results are claimed for millet and barley and are thus concluded to hold generally.

The thermo-stage was induced in a wheat-*Agropyrum* hybrid which was then kept in an 8-hour day for eight months. Even at the end of this time the tissues continued to stain blue, though when the plants were transferred to other light conditions they progressed to later stages and staining changed to greenish or grey (reversibility of vernalization Section I. Ljubimenko p. 18).

Similar tests were made to detect the completion of the photo-stage, examining the inner epidermis of the leaves of cotton and wheats which had passed both the photo- and the thermo-stage (fruiting plants), whilst controls had only passed the thermo-stage (non-fruiting plants). Various dyes were tested, of which the following alone gave results : neutral chrysoidin, rhodamin, dahlia and methyl violet. The results obtained are given in the following table.

Table 12.

Stains	Reaction	
	of cells of epidermis of non-fruited plants.	of cells of epidermis of fruited plants.
0.0025 per cent neutral red.	Stain reddish.	Do not stain, or stain very slightly.
0.01 per cent Chrysoidin.	Cells adjacent to stomata stain intense orange.	Do not stain, or certain cells near the stomata stain yellow.
0.01 per cent Rhodamin.	Stain violet-red.	Stain reddish.
0.01 per cent Dahlia.	Some cells are stained.	Do not stain.

Methyl violet in acid solution (HCl) applied to epidermal cells of fruited cotton plants stains these sky blue, but does not stain the cells of non-fruited plants.

The lower epidermis of the leaf of wheat plants treated with a mixture of methylene blue and methyl red shews the following reactions: (a) pink—plants not completed the thermo-stage; (b) blue—completed the thermo-stage; and (c) mauve-pink—completed photo-stage. This confirms the assumed qualitative difference between the thermo- and photo-stages.

The author claims by this technique to be able to determine long before ear formation has begun the number of stages which have been completed.

Another fact of no less importance is the investigation which threw some light on the localization of vernalization. By varying the vital staining of the epidermal cells of different leaves from the same cotton plant, it has been possible to detect differences in the reaction of leaves situated above and below the first flowering bud; the former reacted as in fruited and the latter as in non-fruited plants.

Richter, Rancan and Pekker 44.

Biochemical studies.

The paper deals with attempts to evolve a rapid and reliable method of distinguishing vernalized seeds by changes which occur in the cells of the embryo. A comparative study of the changes in the activity of the enzyme systems (amylases, proteases, peroxidases, and catalases) was carried out by Rancan, using seeds of winter wheats vernalized for different periods. The hydrolytic enzymes increase their activity continually throughout the pre-sowing treatment whereas peroxidase reaches maximum activity on the 15th day with a secondary maximum at the 39th day, the corresponding dates for catalase being the 20th and 25th days respectively. The maxima are followed by a sharp decline in activity to the initial state in a dormant seed. Comparative studies of respiration, pH and buffer capacity shewed that maximum of respiration, together with minimum of pH and buffer capacity also occur on the 15th day. These correlations however cannot be used as a practical method of diagnosing vernalization. The method adopted depends on diagnosis in staining of albumino-lipoids in the embryonic cells, originally suggested by Bassarskaja (Cf. 47). Using fuchsin and methylene blue, the results confirm those of Bassarskaja, vernalized seeds staining more readily and the staining reaction shewing a sharp change at the end of vernalization.

The embryos of vernalized and sown seeds were stained with toluidine blue 1/600 molar concentration in solutions of varying pH obtained with phosphate buffers.

In the most acid solution (pH 3.8), unvernallized embryos remained unstained whereas vernalized embryos stained quickly. With increasing pH the intensity of staining in both rises, but even at pH 8.3, the vernalized seeds stained more intensely. On further increase in the pH the unvernallized embryos now stain more intensely than the vernalized. Using the two extreme pH values, 3.8 and 9.2, staining is greater with unvernallized seeds at the lower pH, while the reverse holds for the high pH.

Richter 45.

Iso-electric point.

This paper deals with an investigation of the iso-electric point of the tissues as affected by vernalization. The plants used were winter wheat and American cotton. The embryos were extracted, fixed, dehydrated in ethyl alcohol, passed through xylol and finally embedded in paraffin. Microtome sections were prepared and were treated with buffer mixtures ranging in pH from 2.2 to 9.2 (Sørensen, McIlvain). A freshly prepared mixture of 1 per cent eosin and methylene blue was used in which the sections were stained for exactly 5 mins. The surplus was removed with distilled water and the sections were then returned for a further 5-6 hours to the original buffer solutions in which they had been treated before staining. At a certain point in the range a sharp reversal in staining occurred. This critical pH was different in vernalized and unvernallized seeds. At pH 3.9 sections from vernalized seeds stained blue, whereas from unvernallized seeds they were bright red. The iso-electric point in unvernallized seeds therefore lies above pH 4.0 and in vernalized seeds below 3.8. A simpler procedure was evolved for use under field conditions, whereby unfixed material was used, either hand sections or embryo tissue crushed between two glass slides. The results confirmed those obtained in fixed and embedded material.

By tests carried out during vernalization, it was found that the iso-electric point of the tissues changed gradually during chilling and only the completion of vernalization could thus be determined. After 10 days chilling, tissues still stained slightly blue at pH 4.0; at 20-25 days a reddish tinge predominated whereas after 35 days no trace of red remained however long the vernalization process might be continued.

Gavrilova 40.

Iso-electric point.

Richter's method of diagnosis has been applied to an investigation on vernalization of cotton in Tashkent. During vernalization it was found that the iso-electric point of the tissues changed from pH 6 to pH 5.6 during the first 10 days in Navrotskiĭ and 15 days in Acala 8517. On further prolongation of the treatment to 20 days, the iso-electric point returned to the original value. This result is taken to indicate the reversibility of vernalization and field tests of seeds vernalized for 10 to 15 and 15 to 20 days respectively confirmed the result. (See Ljubimenko p. 18).

Sereiskii and Sluckaja 48.

Morphological diagnosis.

The authors have attempted to discriminate between vernalized and unvernallized seedlings by a study of the amount of growth and development. Experiments were performed with winter wheat, Novokrymka 0204. It was found that the rate of development of the leaves of vernalized seedlings was more rapid. Thus in 72 hours the first leaf was fully developed, the second leaf had reached half its final size, and the third was unfolding, whereas in the unvernallized seeds the second

leaf was in the early stages of unfolding. The time taken for full development of the first leaf was 62 hours in unvernialized and 50 in vernalized plants. The corresponding values for the second leaf were 136 and 98 hours, respectively. The plants tested were grown under continuous light (one or two lamps of 300 W. 50 cm. from plants) under strictly comparable conditions.

The authors claim that the difference due to treatment appears only when vernalization is complete. Thus in an experiment with winter wheat vernalized for 15, 23, 34 and 50 days respectively, only the series given 50 days shewed clear differences from the control, 34 days treatment giving smaller differences and the remaining variants no difference. On testing the seeds thus treated, those vernalized for 50 days eared in two months, whereas those receiving 34 days came into ear one month later. The observations lent no support to the supposition that vernalization is reversible.

Demkovskii 38 and 39.

Enzymes.

The work of this author represents the first effort made to study the biochemical changes associated with vernalization. A study was made of the enzyme activity in winter wheat (Stepnjačka), namely, catalases, amylases, proteases. The enzymes were studied on their own substrates in the seeds without adjusting the pH with buffer mixtures, although their effect on other substrates in buffered solutions was tested. The acidity of water extracts of the tissues shewed no variation in pH during vernalization. The activity of the amylase increases by 300 per cent until the 25th day, then falls somewhat, rising again on the 35th day of the pre-sowing treatment. The starch of vernalized and unvernialized samples shewed no variation in resistance to the action of diastase. Proteolytic activity rises continuously throughout the duration of vernalization whereas catalase rises to a maximum (175 per cent) during the first 30 days, falls temporarily, and again reaches a maximum on the 35th day.

The author is well aware of the fact that biochemical changes are not necessarily due to the vernalization process, but may merely represent changes due to aging comparable with those attending loss of vitality on long storage. Nevertheless, it is hoped by this means to demonstrate the degree of vernalization induced by various factors such as temperature or darkness, and so to determine the optimum conditions. The author holds that the evidence for a definite hormone (Cf. Krasnoseljskaja-Maximova, p. 53) can be equally well explained by changes in the enzyme complex.

Čailahjan and Aleksandrovskaia 37.

Length of day and oxidizing enzymes.

Investigations on the activity of the oxidizing enzymes (peroxidases, catalases) of the leaves of millet and barley plants are reported. Samples were taken at regular intervals, starting from the 22nd day, similar leaves on different variants being chosen.

Some of the results for peroxidases are seen in Table 13. It is claimed that the activity of the peroxidases in millet is higher under long days and in barley higher under short days, i.e. in both cases the higher peroxidase activity accompanies retarded reproductive development. In the soya bean and *Phaseolus*, however, the higher peroxidase activity occurs under short day, which favours reproduction.

Table 13.

Variants. Date of Analysis.	Millet.		Barley.	
	Variant 1 : normal day.	Variant 2 : short day.	Variant 1 : normal day.	Variant 2 : short day.
June 22 ..	18.3	13.4	3.5	4.8
„ 25—28 ..	16.2	13.0	1.8	2.2
July 2—3 ..	14.8	12.9	2.3	3.5
„ 8—10 ..	18.1	14.7	1.2	2.5
„ 14—15 ..	19.5	18.7	1.7	3.7
„ 19—21 ..	17.8	17.2	1.3	3.5
„ 26—27 ..	18.8	18.7	2.1	4.4
August 3—4 ..	19.0	18.9	3.3	3.8

B.—DISTINCTION BETWEEN WINTER AND SPRING FORMS.

Krasnoseljskaja-Maximova, etc. 43.**Winter and spring varieties.**

It is claimed that morphological differences are apparent between terminal growing points of winter and spring varieties of cereals: the growing point of the winter varieties remains for a long time small and domeshaped, whereas that of spring varieties soon becomes elongated. The time required for the differences to become apparent varies in different cereals; thus in oats and barley it is noticeable five days after sowing, in rye 10 days, soft wheat in 15-17 days, and in hard wheats in 20 days.

No sharp demarcation exists between winter and spring forms, though it is claimed that by examination of the form of the growing point relative earliness can be predicted.

If by a change in conditions succeeding germination (vernalization) a winter variety be induced to behave as a spring variety, a corresponding change in the form of the growing point is noted.

Čailahjan 36.**Light and chlorophyll.**

The author studied the effect of exposure to varying periods of daylight on the formation of chlorophyll in plants. Garner and Allard and Tincker point out that leaves of plants exposed to short days are often of a deeper green colour than control plants in full days. Ljubimenko and Ščeglova by spectrocoulometric methods have demonstrated that there is an optimum length of day for chlorophyll formation, short days sometimes leading to decrease.

The following plants were used.

Long day plants: *Triticum vulgare* (v. *erythrospermum* 0341),
Pisum sativum (v. Victoria Strube).

Short day plants: *Panicum miliaceum* (Saratov exp. station),
Soja hispida (v. Krušulja).

The plants were grown in pot culture either in full day (16 - 18 hours) or short day (10 hours); 15 days from germination the short day plants appeared paler, and this was confirmed spectroscopically by the method of Ljubimenko and Danilov.

The results of the chlorophyll estimation are given in Table 14.

Table 14. Chlorophyll content in the leaves.

Plant.	Amount of chlorophyll.			
	15 days after sprouting (16.vii)		43 days after sprouting (13.viii)	
	Natural (long) day	10 hour day	Natural (long) day	10 hour day.
<i>Panicum mihaceum</i>	1.92	0.72	1.67	2.32
<i>Soja hispida</i>	1.26	1.05	1.07	2.94
<i>Triticum vulgare</i>	1.66	1.59	2.66	3.44
<i>Pisum sativum</i>	1.39	1.52	1.81	1.96

The results in the Table shew that in the early stages of growth the chlorophyll content of the short day plants is considerably reduced by exposure to short days. Later however more chlorophyll is formed in short days by short-day plants.

In the early stages the long day plants shew little photoperiodic effect, but in later stages of development short exposure intensifies chlorophyll formation in both types of plant.

The results are compared with those obtained by Ljubimenko, who compared the absolute chlorophyll contents of 231 species in Leningrad (lat. 60°N.), 244 species in the Crimea (lat. 45°N.) and 200 species in Java (lat. 6°S.). The mean values of chlorophyll for the three sets (grms. chlorophyll per 1 kg. fresh weight of leaves) were 2.36 grms., 2.52 grms. and 2.66 grms. respectively. The data of the same author shew that the maximum chlorophyll content rises from 3.80 grms. in lat. 60°N. to 4.80 grms. at lat. 45°N., and 7.90 grms. at the equator. Ljubimenko distinguishes "light loving" (photophilous) and "shade loving" plants, and considers that light intensity and temperature are the chief factors determining chlorophyll content. The present author considers the variation in length of day at various latitudes to be an important factor in the relation.

Čailahjan 33 and 34.

Chlorophyll in cereals.

The difference between spring and winter races can be traced to the difference in the conditions under which the two groups have evolved, and have now come to consist not only of visible morphological differences, but also profound differences in the physiological processes. Thus, the winter cereals shew a greater resistance of the protoplasm to frost, whereas with regard to light every gradation can be detected between the two extremes. One of the expressions of these gradations is found in the different chlorophyll contents of the different forms.

To study this aspect, observations were made on a large selection of barleys and winter and spring wheats from different localities.

When the plants were raised in continuous electric light, the leaves of the winter wheats accumulated more chlorophyll than those of spring wheats. Winter and spring barleys shewed a similar correlation. Thus a positive correlation between the capacity for maximum chlorophyll development and winter habit was established. To determine the rate of formation of chlorophyll in spring and winter forms etiolated seedlings were grown for 7 days in the dark and then exposed to light for varying periods and their chlorophyll contents determined. The general trend of the curves was similar for spring and winter wheats. There was a continuous

rise for periods of exposure up to 24 hours, but from the very first hours of exposure more chlorophyll was formed in the winter than in the spring wheats. The behaviour of the plants under an artificially shortened day was analogous. The chlorophyll content of the leaves was greater during the short day as compared with a natural day, from which it is argued that a greater maximum capacity and an increased rate of formation of chlorophyll in winter cereals is their adaptation to the short days of the autumn period, during which the first phases of their development take place.

The inverse process, namely chlorophyll decomposition, was investigated on green seedlings placed in the dark for 5-10 days. In this case still more pronounced differences were observed between the spring and winter forms. Thus the quantity of chlorophyll decomposed in winter wheats was equal to 42 to 73 per cent and in spring wheats 73 to 90 per cent of the original quantity of chlorophyll.

Owing to the absence of complete correlation and the overlapping in certain cases of the spring and winter forms, the use of chlorophyll estimations for diagnosis of such forms is possible only in combination with some other characteristic which divides the cereals roughly into two groups. The leaves of soft spring wheats were found to differ from those of winter wheats by a greater density of the hairs and their greater length. The combination of an increased formation of chlorophyll with a lesser degree of pubescence in winter cereals and of a relatively low chlorophyll content with an abundant, occasionally felty pubescence in spring cereals proved a more reliable criterion than each of these characteristics considered separately.

Čailahjan 35.

Chlorophyll and pubescence.

Just as the chlorophyll content can be used to distinguish spring and winter forms, the pubescence of the first leaf has been shown to be a similar distinguishing feature, all soft spring wheats having long hairs on the first leaf, soft winter wheats shorter, less densely distributed hairs and spring Durum varieties none or very sparse and very short hairs. The degree of pubescence is directly correlated with the chlorophyll content, and by combining the two characters an absolutely certain diagnosis can be made into spring or winter forms eight days after sowing.

After growing wheat seedlings in continuous light for 8-9 days at a temperature of 25°C. and then subjecting them to darkness at the same temperature for 5 days, the chlorophyll began to disappear. The chlorophyll content was determined before the period of darkness; the total chlorophyll content was higher in the winter forms and the loss of chlorophyll in these was moreover distinctly less during the period of darkness. The loss of chlorophyll varied from 0 to 41.4 per cent; only one of the winter wheats lost as much as 24.8 per cent and two of them remained unchanged.

In similar experiments after ten days darkness the loss of chlorophyll was 73-90 per cent for the spring and 42-73 per cent for the winter wheats. The greater loss of chlorophyll is ascribed to difference in the activity of the oxidizing enzymes.

Thus the differences in chlorophyll content between spring and winter forms are much more pronounced after the period of darkness than before and by this means alone the spring and winter forms can be distinguished.

Krasnoseljskaja-Maximova 41.

Internal causes of delayed earing.

This paper deals with experiments designed to test the hypothesis of the existence of some definite substance responsible for differences in behaviour of winter and spring varieties of cereals.

On the basis of the C/N ratio of Klebs, some investigators attempted to bring about reproduction by germinating or storing germinated seeds in various sugar solutions. Both these attempts failed owing to the incapacity of germinating seeds

to take up sugars in sufficient amount. The author therefore attempted to provide the growing embryo with various substances by introducing them directly into the endosperm, and thus to influence the time of reproduction.

Experiments were conducted on *Avena byzantina* No. 1732, an alternative cereal, winter wheat (Kooperatoroka), and spring wheat (Marquis).

Grains of these cereals (the glume having been removed previously in the case of oats) were sprouted for 3-4 days; then through a split made along the softened grains, part of the endosperm ($\frac{1}{3}$ to $\frac{1}{2}$) was removed and the substance to be tested inserted in its place; the margins of the slit were then closed and covered with plaster of Paris. Control seeds were subjected to a similar operation except that the part of the endosperm which had been removed was replaced in the seed. The total number of seeds operated in this way was about 4,000 and it was found that the grains of oats and wheat stood the operation well and produced quite sound plants which came into ear simultaneously with those from unoperated seeds.

(1) The results of the experiments shewed that the introduction of sugars (saccharose, glucose, fructose and maltose), nitrogenous substances (asparagin, glyocol, and pepsin and yeast, heated or unheated, did not influence the beginning of reproduction in winter and spring cereals, and somewhat retarded earing in spring wheat and oats.

(2) Assuming that spring cereals contain a specific substance promoting reproduction, pulp prepared from young grains sprouted from 5 - 6 days or the ovaries and stamens of spring wheat, was introduced into the seeds of winter and spring wheat and oats. This however failed to affect the time of reproduction of either form of cereal.

(3) On the assumption that winter forms contain a substance which retards reproduction and that the introduction of pulp prepared from parts of winter forms into seeds of spring and alternative forms will retard their reproduction, further experiments were made with the introduction of pulp prepared from seeds of Kooperatoroka which had been sprouted for 5 - 6 days into the endosperm of *Avena byzantina* and Marquis wheat. The reproduction of *A. byzantina* was retarded by two weeks, but Marquis eared simultaneously with the control. The introduction of pulp prepared from seedlings of Kooperatoroka kept for six weeks at 0°C. retarded reproduction similarly; the operated plants of oats produced their first panicle 5 days later than the control and during the following 3 days 28 experimental plants produced only 8 panicles, whereas 20 control plants gave 20 panicles.

Since Kooperatoroka is not considered to be a typical winter form, *Lutescens* 329 was introduced into later experiments. Pulp from this type had a more retarding effect than that from Kooperatoroka, although the vigour of the plant was not affected. Thus, the emergence of the first panicle on oat plants produced from seeds treated with *Lutescens* pulp was 20 days later than the control and 13 days later than those treated with Kooperatoroka pulp. The delay in earing was not due to a reduction in general growth and vigour, as is shewn by the number of panicles eventually obtained. This was as follows:—from 14 control plants, 45; from 39 plants previously treated with Kooperatoroka pulp, 135; and from 19 plants treated with *Lutescens* pulp, 73, i.e. the introduction of pulp even stimulates the tillering of plants before they proceed to shoot.

In order to study the nature of the substance retarding earing in winter forms, some pulp was kept in the air for one hour before introduction (control) and the remainder was heated in a water bath for 5 and 15 minutes. The retarding power of the heated pulp was much reduced; the percentage of plants with ears were: untreated 74, treated with heated pulp 50, and treated with unheated pulp 10.

Further experiments shewed that the introduction of winter pulp retards the

development of the growing point of spring cereals, and thus the retarding influence of winter pulp can be detected long before the time of earing.

On the basis of these experiments the author concludes that "winter wheats contain a substance of the hormone type which retards reproduction. This substance can be said to be the hindering factor which conditions the differences between winter and spring forms," and the effect of the substance is stronger the more winter the habit of the variety. The fact that in these experiments pulp from wheat retarded earing of oats indicates the need to investigate how far this substance is common to all plants. As regards spring forms, the author was unable to detect in them any substance accelerating the earing.

Sereiskii and Sluckaja 47.

Hormones denied.

Further work on the possible role of hormones in determining the behaviour of spring and winter forms is described. Winter wheat *Ferrugineum 1316/2* was used, the seeds being vernalized at 0-2°C. from April 19 to June 13 in the first experiment and from December 13 to January 24 in the second. The control seeds were unvernallized.

(1) Using the technique of Krasnoseljskaja-Maximova crushed tissue of vernalized seeds was introduced into the endosperm of unvernallized seeds and vice versa. The treated seeds were grown under continuous light. Under these conditions in December all variants had produced stems and even ears. It was therefore assumed that the plant used was not a typical winter variety. It is concluded that the introduction of pulp had no effect on the time of earing and indeed appeared to stimulate vegetative growth in both vernalized and unvernallized seeds.

(2) Further experiments were performed in which germinating seeds vernalized and unvernallized were cut transversely and the two half seeds were fixed tightly together with plaster of Paris.

The following variants were used :—

Two unvernallized halves both with embryo	..	..	..	Variant	1
Unvernallized half + vernalized half both with embryo	..	..	..	..	2
Two vernalized halves both with embryo	..	..	..	..	3
Two unvernallized halves with one embryo	..	..	..	..	4
Unvernallized half with embryo + vernalized half without embryo	..	..	..	..	5
Unvernallized half without embryo + vernalized half with embryo	..	..	..	..	6
Vernalized half with one embryo	..	..	..	..	7

It was found that in no case was there any interaction between the halves of the seeds thus joined, each half behaving quite in accordance with its own state of vernalization. Examination shewed that no tissue changes had taken place at the cut surfaces tending to isolate the two halves. The authors hold that these experiments disprove the existence of a special inhibitor in the winter wheat. On the other hand, vernalization is held to be due to changes occurring actually in the meristematic tissue which cannot be translocated to other cells but can only influence development through cell division.

Krasnoseljskaja-Maximova 42.

Animal hormones.

In the study of the internal causes of the transition of plants to reproduction, the author in 1932 made an experiment with an operative introduction of ovarin, prolan, masclin and insulin into a softened endosperm of the seed of *Avena byzantina* 1732 previously germinated for two days at room temperature ; control seeds were subjected to a similar operation without the hormones.

All four experimental groups, as compared with the control, shewed a more vigorous vegetative development and retarded reproduction. The retarded reproduction, however, when it did commence, was at least equivalent and in certain cases even superior in vigour to that of the control. The experiment had to be terminated owing to fungous diseases before seed maturity.

Although the influence of all the tested hormones was essentially of the same nature, the strength of their action was, however, not similar; ovarin proved to be most effective, prolan somewhat less and insulin and mascrin still less effective.

Rubin and Naumova 46.

Enzymes and lateness.

The preliminary investigations, concerned mainly with the action of enzymes, particularly that of catalases, and relative earliness, were made on early and late radishes (*Raphanus sativus*) and cabbages (*Brassica oleracea*). Samples prepared from 50 plants were studied in respect of catalases (by the method of Bach and Oparin), amylases and saccharases (by Euler's method).

A comparative study of radish varieties shewed that in *R. sativus* var. *radicula* the activity of all three enzymes, particularly catalases, both in the leaves and roots is, as a rule, higher in earlier than in late varieties. The greatest difference (95.9 per cent) was found to exist between catalases of early and late varieties in roots at the stage of commercial maturity. This difference falls gradually until the beginning of flower development and then rises again. At the stage of the third leaf, the difference (18 per cent) is a reliable indication of the relative earliness of the variety. Early varieties shewed no greater saccharase activity than late varieties, but on the contrary, at the early stages of development the saccharases may be somewhat more active in late varieties; at later stages, however, increased activity is found in early varieties and the difference gradually increases reaching 50 per cent at the stage of commercial maturity. No demonstrable difference in amylases was found to exist between early and late varieties.

In *R. sativus* var. *niger* only the action of catalases was studied; this proved to be considerably greater in early than in late varieties, reaching 20 per cent on the 20th day of development. The difference in the action of catalases is particularly great in roots, and on the 55th day early varieties shewed a four-fold increase over the late ones. In the cabbage the catalases were studied only at an early stage and the data are not given.

On the whole, the authors conclude that the data obtained indicate a certain correlation between the energy of plant development and the action of some enzymes (particularly catalases).

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4. VERNALIZATION OF VARIOUS AGRICULTURAL PLANTS.

A.—TECHNIQUE.

Lysenko and Stepanenko 72.

Savchenko—Beljskii 85.

Comments on technique for cereals.

In making use of vernalization in practice, the choice of suitable varieties is of primary importance. In some localities spring sowings, and especially ultra-early spring sowings of the winter wheats *Ukrainka* and *Kooperatorka* have given results definitely better than those obtained with the spring varieties commonly used; but in many districts at present it is recommended that only the spring wheat varieties grown there should be used for vernalization. In this way their date of maturity is made earlier and the quality of their yield is improved, whereas many winter wheats even after vernalization are too late in maturity to be a success.

No recommendations can yet be given as to suitable varieties of barley and oats for vernalization, though late barley varieties are thought to be most promising.

The technique for all plants is the same in respect of certain essential features, namely, that the seeds must be made to germinate, but without the radicle penetrating the seed coat, and that their further development must be artificially arrested at this stage while the treatment is applied. However, the moisture content, the temperature and the length of treatment vary for each variety. Thus for every 100 kg. of seed of normal moisture (12-14 per cent) winter wheat varieties require 37 litres of water, late spring varieties require 33 litres and early varieties 31. Without these full amounts of water the process of vernalization will not proceed normally. The water must be applied in three successive stages in order to ensure complete absorption, and thorough mixing is also important for the same reason. Winter wheat and winter barley must be kept for 2-3 days in the pile, adjusting the temperature to 5-10°C., for germination to begin, whereupon, when 3-5 per cent of the seeds have burst their coats, the temperature is reduced to that required by the variety, in the case of winter wheat 0-2°C. The period of vernalization is counted only from this time.

Care must be taken to maintain an adequate moisture and if after 15-20 days it is found that not all the grains have burst, more water must be added, otherwise the vernalizing process will cease. About 5-8 litres of water per 100 kg. of grain may be added. On the other hand if the seeds are too moist they will sprout, and this must be avoided by adding a suitable quantity of dry grain of the same variety—up to 10 per cent may be added.

If the grains have to be disinfected for bunt, etc., this can be done at the second moistening, but only formalin should be used; other preparations must be carefully avoided owing to their possible effect in reducing the germinating capacity of the grain.

The varietal requirements with regard to temperature also differ, winter cereals being treated at a temperature not higher than +2-3°C. and not below 0°C.; late spring varieties require a temperature not below +3°C. and not above 5-6°C., while early spring varieties of both hard and soft wheat must be treated still higher, at 8-10°C., but not higher than 15°C.

The winter cereals need the longest treatment, varying from 40 to 50 days, according to the variety; thus for *Kooperatorka* wheat the time is 40 days, for *Ukrainka* 45 and *Hostianum* 0237, 50 days. On the other hand the time for spring

cereals is much less, 10-15 days for the late forms and 5-6 for early spring varieties of soft and hard wheat.

The treatment for oats and barley is exactly the same as for late Durum wheat except in the quantity of water for moistening. Most winter barleys require about 35 days treatment for ordinary sowing and 20-25 for ultra-early sowing. Winter barleys require the same proportion of water as winter wheat, namely 37 litres per 100 kg. of seed, regardless of variety, while for spring varieties of oats and barley only 35 litres are necessary.

The aeration of the seeds is another important feature in successful vernalization. Since the temperature necessary for spring cereals is not so low as for winter cereals it is possible in this case to carry out vernalization in sacks of fairly thin material; in this way a better aeration is ensured, while there is no risk of the temperature rising too high as in winter cereals; these must always be treated in a thin layer on the floor to maintain the low temperature. In controlling the temperature, it is essential to take the readings within the heap of seeds and not that of the air. Even hard spring wheat must not be allowed to rise above 7°C., so as to prevent undue sprouting and damage by moulds; for soft spring wheat a temperature of 10°C. should be maintained.

Sowing should be done immediately after vernalization, to which end the treatment should be started only at a time calculated to yield the finished product on the date of sowing. If large quantities are to be sown, only so much seed should be started each day as can be sown in a day. If for any reason it is not possible to sow immediately, the growth of the embryos must be restrained by keeping the seeds in a thin layer at as low a temperature as possible, though not below zero. No delay is permissible with winter cereals, beyond 10-15 days, during which the above method may be adequate. Drying can also be resorted to, by adding 20-30 per cent of untreated seed of the same variety, but the best method is to put the vernalized grain through a winnowing machine.

Since vernalized seeds are larger and heavier than normal seeds care must be taken to sow the same number of seeds per hectare, not merely the same weight. The best way to ensure this is to measure the seed before vernalization, treating the seed for each section of the field, say sections of 2-3 ha., separately.

It is recommended that winter wheat and winter barley should be sown in the mud, the so-called ultra-early sowing, in which case the last 10 days of the treatment, which are the most difficult to carry out, can be omitted. Spring varieties must, however, be sown at the same time as the unvernallized crop is usually sown.

Bassarskaja 49.

Retardation of growth.

It is frequently found necessary to treat seeds in order to delay germination without reducing their vitality; the usual method of moistening the seeds with a definite amount of water may cause the seeds to suffer in their later development. For this reason the author investigated the direct influence of various salt solutions upon growth.

In the first experiments with the harmless salts of potassium, magnesium and ammonium, it was found to be possible to select concentrations which only retard growth. As the prolonged action of such a salt might eventually be harmful, the ordinary solutions were replaced in later experiments by balanced solutions in which the poisonous effect of the salts was neutralized. Thus the author's attention was directed to solutions of the sea water type.

The remainder of the paper is concerned with experiments on the effect of various solutions on vernalized seeds. Since the pH value of solutions is of great importance for growth, various buffer mixtures were also tested. One of the most suitable solutions for retarding growth in wheat grains during vernalization is a buffer mixture

of sodium phosphate (NaH_2PO_4 and Na_2HPO_4), taken in 0.25 mol. solution and mixed in equal volumes. Mould growth is rare on seed treated with buffer mixtures.*

The results obtained so far indicate that treatment of seeds with chemical solutions does not have any effect on the subsequent development of the plants and on flowering. This however requires confirmation under field conditions.

Gešele 59.

Control of Fungous Diseases.

The moist conditions during vernalization lead to a great danger of mould development, especially when the seeds are treated at rather high temperatures. *Penicillium* forms mainly on wheat, *Trichothecium* on cotton, and *Fusarium* on soya bean and maize. The best way to avoid moulds is to use healthy undamaged seed, and not to start the vernalizing process too soon and have the moist seeds waiting before sowing begins. It is important also that all the apparatus used should be free from spores.

In using disinfectants there is the danger of stimulating growth or of damaging the seeds. Treatment of the slightly moistened seeds with a 0.1 per cent solution of mercuric chloride for 10-15 minutes or with a 0.13 per cent solution of formalin for three minutes is recommended however. The seeds must be washed to remove the disinfectant, immediately in the first case and after two hours in the second and are then moistened in the ordinary way with water. The disinfecting can be done with advantage before the second moistening.

It is possible that a suitable combination of salts will be found in which one will act as a disinfectant and the other will arrest growth. The whole question of suitable disinfectants requires further study.

For bunt the only preparations that can be used with safety are the AB mixture or copper carbonate, to be applied dry after vernalization. Here again there is a great risk of damaging the seed and the most satisfactory method is to disinfect against mould and bunt together, by performing the first moistening with water, the second with 0.13 per cent formalin and the third with water. Milk of lime and mercuric chloride can be used in the same way.

Nemlienko 79.

Control of bunt.

The biological processes occurring in seeds under vernalization provide a new background for an interaction between a host plant and parasite. Presumably the conditions required for vernalization of wheat, namely, the relatively low temperature and the reduced energy and prolonged duration of sprouting, favour the infection of seed by *Tilletia tritici*. On the other hand, the methods of disinfection practised on unvernallized seeds cannot be applied to seeds under vernalization without preliminary test. After a dry disinfection, seeds to be vernalized will necessarily be sprouted in a fungicide solution and this, particularly at high concentration, will undoubtedly interfere both with the sprouting and the vernalizing process. Wet fungicides usually impair germination. Again, disinfection of vernalized seed can adversely influence young seedlings and, moreover, by the time

*In the vernalization of samples of the world collection of wheat carried out by D. A. Dolgušin in 1933-34, seeds were soaked according to the method suggested by Bassarskaja. In his latest publication "The world collection of wheat on the background of vernalization" (Sel'hoz'giz, Moscow, 1936, pp. 110), Dolgušin recommends (pp. 26-7) the following solution: 116 grm. NaCl + 14 grm. KCl + 5 grm. MgSO_4 per 1,000 ccm., and the following buffer mixture: 34.5 grm. NaH_2PO_4 + 89.5 grm. Na_2HPO_4 per 1,000 ccm. Soaking is continued at 15 to 20°C. for 24 hours; the sprouted seeds are afterwards vernalized. If the moisture acquired proves to be insufficient, an additional soaking should be made in water. Drying of seeds after vernalization is not advisable, as the germinability is impaired.

of sowing the vernalized seeds can already be infected and the mycelia within the embryo can easily escape the poison. Thus, the discovery of the time of infection of seeds acquires particular importance in vernalization.

To investigate the problems relevant to the infection of seeds by *T. tritici*, a series of experiments was conducted in 1931 at the Artemovsk Station with the spring wheat *Lutescens* 062 prepared for vernalization at 12 to 14°C. for four days and vernalized at -2° to + 1°C. for 43 days. Before or after vernalization, seeds were infected with bunt spores at the rate of 2 grm. per 1 kg. of seeds and then disinfected with various fungicides. Seeds were sown on April 20 and bunt infection later estimated by counting sound and diseased plants. As a supplementary control the plots sown with seeds unvernallized, but otherwise similarly treated, were used. The following fungicides were tested: formalin (1:300 concentration, 2 hour treatment), copper sulphate (1 per cent solution, 5 min. treatment), AB patent mixture (1.5 grm. per 1 kg. of seed), dehydrated copper sulphate (2.0 grm. per 1 kg. of seed) and granulated "chrompique" (1.5 per 1 kg. of seeds).

The degree of bunt infection in vernalized seeds, when artificially dusted with spores, was one-third that in unvernallized seeds. Thus, the condition of sprouting and vernalization proved to be unfavourable for bunt; presumably part of the spores applied had been killed off in swelling and chilling with the result that seeds after vernalization were less infected by bunt. Nevertheless, after an intensive dusting the degree of bunt infection was so high (7.25 to 8.13 per cent) that disinfection is required. Since bunt infection of seeds dusted before and after vernalization differed little, it was concluded that infection by bunt takes place in the field after sowing, and not during sprouting or vernalization before sowing. The slight natural infection shewed no pronounced difference between unvernallized and vernalized seeds. In an investigation of the bearing of size of vernalized seedlings upon bunt infection, the degree of infection was found to differ little.

All the fungicides, whether dry or wet, disinfected the seeds equally well when applied in the ordinary way before sprouting and vernalization, and the degree of bunt infection on vernalized and unvernallized seeds was below 1 per cent. Moreover, disinfection of seeds before vernalization, particularly with formalin and dry copper sulphate, prevented moulding during vernalization. All the fungicides, however, impaired germination and the percentage of dead seeds was increased by 9.2 per cent after disinfection. All the fungicides, with the exception of formalin, also decreased the energy of sprouting. The author concludes, therefore, that in spite of good results obtained by disinfection, neither dry nor wet fungicides can be used in the ordinary way in vernalization, for the germination of seeds is impaired; different methods of disinfection must be sought.

B.—SPECIAL CROPS, TECHNIQUE AND RESULTS.

CEREALS.

Lysenko 70, 71 and 75.

Spring and winter wheat.

Although the pre-sowing treatment of wheat was not widely practised in the farms of the Soviet Union until 1932, yet the beginnings of the experimental test of vernalization under farm conditions can be dated as far back as 1929 when, on the initiative of T. D. Lysenko, D. N. Lysenko carried out a successful vernalization of winter wheat, Ukrainka, on his own farm. Under the auspices of the NarKomZem* trials were commenced in 1930 on many farms, chiefly in the Ukraine, on vernalization of wheats (chiefly Ukrainka, but occasionally Durable, Jurjevka 76, Hostianum

*Peoples' Commissariat of Agriculture.

237 and some local varieties). The fact that vernalized sowings of Ukrainka suffered from the drought as much as unvernallized indicates that in south Ukraine, Ukrainka even after vernalization was not sufficiently early to escape the drought and that a better variety must be chosen.

Experiments in Odessa during the same year shew that under local conditions the behaviour of Ukrainka after vernalization was much inferior to some other winter wheats such as Novokrymka 0204, Stepnjačka or 714 U.G.S.I., for the latter, being 6 - 8 days earlier, produce a better grain with a higher thousand grain weight (21 - 26 grm.) than Ukrainka (10 grm.) or spring wheat Girka 0274 and 0180 (8 grm.). In other parts of Ukraine, the yield of vernalized sowings varied from 3 to 27 centners per ha. The main factor reducing the size of crop was the thin stands produced because of over-sprouting of seeds before sowing. Chilling was commonly practised by keeping the seeds under snow and with such an imperfect technique the warm spring stimulated the growth of seeds during chilling. It is impossible to form any definite opinion as to the efficiency of vernalization of wheat as compared with spring sowing of spring strains. In addition to a proper choice of varieties, the technique ought to be modified, for in the instructions published by Lysenko and Dolgušin in 1930 some important points were omitted, namely (1) seeds after vernalization can be dried: this enables the farmer to store vernalized seeds for a time before sowing; (2) in vernalization a somewhat reduced moisture will retard the sprouting of seeds; (3) vernalization does not progress at a temperature below -2° or -3°C . and a temperature of about 0°C . can hardly be regarded as optimum; it is quite possible that vernalization will progress more rapidly at somewhat higher temperatures.

In 1932 vernalization of wheat was more widely used in U.S.S.R. and the area under vernalized sowings rose to 43,000 ha., 37,000 of which were in the Ukraine. The plan suggested by NarKömZem for 1932 was not, however, completed, the main obstacle being the novelty of the method. Nevertheless, the size of the experimental plots used in 1932 was considerably larger than in the previous years; in most farms it varied from 10 to 50 ha., while in some it was as large as 100 ha. All the triple questionnaires were, however, not returned duly completed; those received concerned an area of about 20,000 ha.

According to 772 questionnaires, there were only 4 cases when seedling emergence on vernalized sowings was later than on unvernallized sowings; in 97 cases it was similar and in the remaining cases it was 1 to 8 days earlier on vernalized sowings. Estimates of the type of seedling emergence shewed that the "bad" and "average" were more frequent on unvernallized sowings than on vernalized sowings; the "good" examples were more frequent on vernalized sowings. Thickness of the stands produced were thinner on vernalized plots owing to the fact that the sowing machines were not properly adjusted for the heavier and larger vernalized seeds.

Of 274 replies reporting time of earing, in 4 a delay (1 day) on vernalized sowings was reported; in 51 cases earing was simultaneous; and in the remaining cases earing of vernalized sowings was 1 to 8 days earlier; on the average, vernalized plants eared 3 to 4 days earlier than unvernallized. It could be gathered from the reports received that a late sowing retarded the time of earing more on unvernallized sowings than on vernalized sowings. Experiments made in Odessa shewed that late sowings also affected the quality of grain on unvernallized plots. Therefore, in unavoidably late sowings, vernalized seeds should be sown.

It is impossible to draw definite conclusions regarding grain yield. According to 59 questionnaires received, in 13 cases a lower yield was obtained from vernalized plots, in 5 cases it was similar in both and in the remaining cases the grain yield of vernalized sowings was 1 - 3 centn. per ha. higher. An appropriate choice of variety is essential; for example, the most successful vernalized sowings were made in the western parts of U.S.S.R. mostly because Uljka and Lutescens 062 were used and

those varieties proved to be suitable for vernalization in these regions. The rise of grain yield is due mainly to the better quality of the grain. Near Odessa where the results from vernalization were generally not very marked, some very successful sowings were made by vernalizing soft wheats and Arnautka. Thus, in addition to better technique in vernalization and in the sowing of vernalized seed, greater attention must be given to the choice of variety to be used.

Vernalization in 1933 was not only applied on a larger scale (200,000 ha.) but was more successful than in the previous years. According to replies received from 1056 farms scattered all over the Union, seedling emergence of vernalized sowings was generally 3 to 4 days earlier and more simultaneous than on unvernallized plots. In 549 cases seedling emergence of vernalized plots was "good," in 386 cases "average," and in 16 cases "bad," whereas 408 "good" examples were noted in unvernallized plots, 489 "average" and 31 "bad." In almost all cases, earlier earing and better quality grain were reported from vernalized plots. The size of the grain yield was also increased. The better results of 1933 should be ascribed mainly to improvements in technique. Thin seeding is however still reported and lower yields are due mainly to this cause.

Vernalization of wheat in 1934 was carried out on 25,000 farms on an area of over 500,000 ha. According to questionnaires so far received vernalization was still more successful than in 1933 in spite of a less favourable season. The average increase in grain yield for the whole Union as a result of vernalization was 1.13 centn. per ha.

Thus three years' application of vernalization under farm conditions has not only proved the efficiency of vernalization of wheat but also made it possible to improve and revise the technique of vernalization for farmers. Experience of the past years shewed that in pre-sowing treatment it is the humidity, and not the temperature, which is the critical factor and that this should be regulated according to the temperature during vernalization. On the whole the lower the temperature at which vernalization is carried out the higher should be the humidity of the seeds. It should be noted that neither humidity nor temperature alone is decisive, but their combination, as by changing one factor it is possible to increase the effect of the complex of factors and thus to create the optimum conditions for vernalization. It was found during more recent years that drying of vernalized seeds before sowing should be avoided as far as possible, for this drying tends to reduce the germinability.

Flaksberger 55.

Wheat.

In 1932 over 5,000 specimens of the world wheat collection were vernalized, which together with Lysenko's own collection of Azerbaijan wheats made a total of 6,300 in all. They were sown on the 16th April, under uniform conditions, and each specimen was sown vernalized and unvernallized. The author visited the station and examined the experiments on the 24th-26th June.

In the case of spring wheats, those of the following countries had come into ear when vernalized whilst the ears of the unvernallized controls had not yet emerged: Italy, Sardinia, France, Switzerland, Bavaria, Yugoslavia, Bulgaria, Greece (a few) Asia Minor, Tunis, Afghanistan, Georgia, Azerbaijan and U.S.S.R.

Other varieties had both come into ear, vernalized and unvernallized, among these being wheats from Finland, France, Italy, Portugal, Norway, Latvia, Austria, Yugoslavia, Czechoslovakia, Bulgaria, Sicily, Malta, Greece, Crete, Rhodes, Cyprus, Algeria, Morocco, Tunis, Egypt, Abyssinia, South America, Transvaal, Asia Minor, Syria, Palestine, Persia, Afghanistan, Manchuria, China, Japan, India, North America, Mexico, Guatemala, Peru, Uruguay, Colombia, Georgia, Azerbaijan, Armenia, Dagestan, Uzbekistan. In these varieties vernalization had either made no difference or only slightly accelerated ear emergence.

In a further group neither the vernalized nor the control plants had come into ear, this group consisting of wheats from Sweden, Holland, England, Germany, Poland, Sardinia, Kashgar and certain ones from North America. In some of these vernalization had effected a certain acceleration of development, but not enough to lead to ear emergence.

The ultra-early wheats of Arabia were peculiar in that the vernalized plants had not yet eared though the controls had. Lysenko remarked that these wheats had been damaged during vernalization, but it is possible that in this ultra-early group the process has a definitely negative effect.

Winter wheats from a number of countries had shewn marked response in that the vernalized plants had eared and the controls had not even formed stems, namely wheats from Czechoslovakia, Yugoslavia, France, Germany, Italy (a few), Sicily, Rhodes, Asia Minor, Morocco, India, China, Japan, North America, Peru, Afghanistan, Uzbekistan and Azerbaijan.

The vernalized plants had begun to shoot, but the ears had not emerged in another group from Italy, Germany, Switzerland, France, Latvia, Poland, Bavaria, Holland, Moravia, Arabia, Hungary, Rumania, Greece, North America, Georgia, Armenia, Dagestan, Afghanistan and Uzbekistan.

No effect was observed in a group of varieties from Sweden, Finland, Germany, Norway, Denmark, Latvia, Poland, Holland, England, Moravia, Rhodes, Morocco, Algeria, Tasmania, Asia Minor [very few], Georgia, America, Dagestan, Afghanistan, Uzbekistan, Japan, Korea and Transvaal, in which neither vernalized nor controls had come into ear.

It is clear that different ecological types require different treatment for vernalization. The wheats of certain countries represent a uniform ecological type and react alike to a particular treatment, whereas other countries, including the U.S.S.R., contain groups reacting differently to the same treatment and thus representing different ecological types.

Maximčuk 76.

Winter wheat.

In this early experiment made in 1928-1929 on the pre-sowing chilling of winter wheats (Ukrainka and Kooperatorka) seeds were soaked at room temperature and after slight drying were chilled in snow at -2.5°C . and then sown on two dates, namely, on the 44th (early) and the 73rd day (late) after the commencement of chilling. In the early stages the development of seedlings in all sowings was more or less normal but only the plants of the late sowings reached the shooting and earing stage. In both varieties earing began on July 15 and complete maturity was reached on August 20. Estimates made at harvest time shewed that in plots 2.25 sq.m. in size Kooperatorka produced 325 plants, 163 of which eared, and Ukrainka produced 34 plants, 12 of which yielded grain. Moreover, the plants of Kooperatorka has more or less normal ears whereas those of Ukrainka had hardly emerged from their sheath.

A comparative study of the effects of pre-sowing chilling was made in two winter sowings (Sept. 4 and 26 respectively) of the same wheats. Both in rate of development (the onset of vegetative phases such as tillering, shooting, earing, and complete maturity) and in the energy of growth and development (number of tillers and spikelets on an ear, weight of one plant, ear and grains, etc.), the winter sowings, more particularly the earlier one, were much superior to vernalized spring sowings. All the phases studied began later in vernalized plants.

Grain yield was not recorded owing to the small number of vernalized plants, but it was concluded that vernalized plants would also be considerably inferior in this respect.

While refraining from any final conclusions as to the efficiency of vernalized and

autumn sowings of winter wheats and spring sowing of spring wheats, the author stresses the fact that although the method suggested by Lysenko is very valuable from the theoretical point of view, it should be thoroughly revised and modified for adoption in agricultural practice, for at the time of writing it was not known for most wheat varieties (1) how long they should be chilled before sowing, (2) at what temperatures they should be chilled, (3) when and how they should be sown after chilling, and (4) how vernalized sowings compare with ordinary autumn sowings.

Schulz 86.

Wheat.

In 1934 in the non-chernozem region spring wheats including three local varieties, *Caesium 0111* and *Lutescens 062* were vernalized and sown in a number of collective farms. The vernalized wheat out-yielded the unvernized by 2-4 centner per ha. The use of ultra-early sowing of spring wheat to effect natural vernalization is also recommended.

Varfolomeeva 92.

Wheat.

Tests were made in 1932 in N. Caucasus of a number of local strains of spring wheat, both *Triticum vulgare* and *T. durum*, which had been vernalized. There were 33 late spring varieties of *T. durum*, of which 26 showed acceleration in earing after treatment, and 20 early varieties, of which 8 showed acceleration. The emergence of the seedlings was 1-3 days earlier in the treated plots and most of the late varieties after treatment eared together on the 26th-27th June, whereas the earing period of the untreated extended from 27th June to 4th July. The treated late wheats were thus as early as the local standard, *T. durum hordeiforme 0189*, which when untreated eared on 27th June in 1932.

The experiments in 1932 were done on an area of 2.5 sq.m. only but in 1933 were repeated on 75 sq.m. Twenty-four late varieties of *T. durum*, three new selections of the station and four standard wheats were tested. The treatment was that recommended for late varieties except in the case of the standard varieties and the three new selections, which were treated also by the method for early varieties. Of the 31 varieties treated by the method for late varieties 25 showed accelerations in earing of 1 to 5 days and of the 7 varieties treated by the early variety method 4 gave accelerations of 1 to 3 days.

The late varieties of *T. durum* reacted more than the early ones, both in 1932 and 1933. The crop suffered from abnormal drought in both years but 15 out of the 24 late varieties tested showed yield increases as a result of treatment, the increases varying from 6 to 58 per cent.

The standard varieties gave little or no acceleration in both methods of treatment but *Hordeiforme 0189*, though not accelerated in ear emergence, showed in each case an increase in yield. An earlier maturing standard variety, *Melanopus 069*, reacted definitely more to the treatment for early varieties than to the treatment for late varieties, and *Caesium 0111* showed a slightly greater yield increase in the treatment for early varieties, though its ear emergence was accelerated only by 1-2 days.

When treatment was applied to the whole world collection of wheats at the Bezenchuk station 950 of them (26.5 per cent) gave no acceleration in ear emergence. However the size, quality and weight of grain was increased in nearly all varieties.

The conclusion is therefore reached that vernalization is a valuable agronomic measure, increasing the yield and quality of grain as well as the earliness, and its wide application in practice is recommended.

Zenjuk 93.

Spring wheat on peat soil.

Peat soil is less suitable for cultivation than an ordinary mineral soil; in addi-

tion to a reduced vegetative season owing to late spring and early autumn frosts, the vegetative period of plants cultivated on peat soil is frequently prolonged by 10 to 15 days or more. Considering vernalization primarily as a method of accelerating plant development, experiments were made at the Minsk Marshland Station in 1934 on (1) the effect of vernalization on the yield of the wheats *Lutescens* 062 and *Caesium* 111, and (2) a comparison of the effect of vernalization on seeds previously sprouted in water and in a 0.1 per cent pyrogallol solution (*Lutescens* 062).

While vernalization accelerated the onset of the early developmental phases it did not affect the phases subsequent to ear emergence, nor the grain or straw yield. In the second investigation plants produced from seeds sprouted in pyrogallol showed an increase in grain yield from 16.00 to 23.41 centn. per ha., and in straw yield from 34.44 to 38.14 centn. per ha. Vernalization had the same effect on seeds sprouted in water or in pyrogallol, all developmental phases being earlier.

Data are also available regarding the spring wheat *Lutescens* 062 sown vernalized and unvernallized on different dates. Late sowings, whether vernalized or not, developed more quickly and earing was almost simultaneous with the early sowings. In later sowings (May 3), vernalization accelerated the onset of all developmental phases, whereas in early sowings the difference was evident only at the early phases preceding ear emergence.

Muravjev 78.

Milling and baking quality.

In the practical application of vernalization to wheat, two points are important: (1) how far unsown vernalized seeds can be used for making flour, and (2) whether grain from vernalized plants is in any way superior.

Observations made on the milling and baking qualities of unsown but vernalized wheat showed that the former was distinctly reduced. The baking quality in some varieties was not affected unless the grain had sprouted excessively and occasionally was even increased. By adding flour from sprouted vernalized grain to flour of low baking quality the quality was markedly improved, largely on account of the increased diastatic activity.

To investigate the quality of grain obtained from vernalized wheat plants, two experiments were made in 1931 at Odessa. In the first two Azerbaijan wheats, *Ferrugineum* 1316/8 and *Erythrospermum* 534/1, were sown vernalized and un-

Table 15.

Variety.	Hectolitic weight.	1,000 grain weight.	Percentage of transparent grains.	Percentage of flour yield.	Volume of bread.	Increase in weight on baking in percentage.	Porous texture.	Baking estimation.
Girka 0274, standard variety ..	74.9	17.4	71	72.0	602	42	90	97
Ferrugineum 1316/8, vernalized	78.2	26.5	70	74.7	617	40	100	105
Erythrospermum 534/1, vernalized	82.0	22.6	90	74.3	522	45	73	88
Stepnjačka, sown in autumn ..	80.4	28.4	82	71.2	580	45	80	95
Stepnjačka, sown vernalized ..	77.6	25.3	92	73.7	625	42	95	103

vernalized in spring. Only a few grains were produced from the unvernallized wheats, with 1000-grain weight of 10-11 gm. and hectolitre weight of 65-67 gm., while total yield was insufficient for analysis. Data for vernalized wheats, with Girka 0274 (local standard variety) included for comparison, are given in Table 15. Excellent results were obtained, Ferrugineum 1316/8 equalling the best wheats of Russia and America.

The second experiment was made with winter wheat Stepnjačka 0496 sown unvernallized in autumn and vernalized in spring. Data are incorporated in Table 15.

It is considered that these preliminary data cannot be ignored. A test of all varieties on the basis of vernalization should be made to determine the earliest and best as regards milling and baking quality.

Gedinov 58.

Wheat and oats.

In a collective farm in the Central Volga region twenty hectares were sown under vernalized wheat in 1934. On 19th June the vernalized sowings were 50 cm. in height whilst the unvernallized controls were only 40 cm. The stand in the vernalized plots was 95 plants per sq. m. and only 78 in the controls.

The heights of the vernalized and control wheats in the beginning of July were 110-120 cm. and 95-100 cm. respectively, the number of plants per sq. m. 199 and 202 respectively. On the other hand the number of ears per sq. m. was 258 and 187 respectively. In the vernalized plots the number of plants with one ear was 126, with two ears 45 and with three ears 14, whereas in the control there were 154 with one ear, 20 with two and only 1 with three. Thus the number of plants with more than one ear amounted to 59, or 29.6 per cent in the treated and 21, or 13.9 per cent, in the control. There were also 27 (13.3 per cent) undeveloped plants in the control plot as opposed to 14 (7 per cent) in the vernalized.

Similarly in oats the stand in the vernalized plots was 135 plants per sq. m. in the vernalized and 95 in the unvernallized, the respective plant heights being 55 and 47 cm.

The vernalized seedlings appeared above ground on the 4th, the unvernallized on the 7th day.

Fokeev and Vyrov 56 and 57.

Wheat, millet and potato.

The results of agricultural vernalization in 1933 stimulated its wider application in 1934 in the Central Volga Region, where practically the entire planned area of 300,000 ha. was sown with vernalized seeds. Such a wide use of vernalization in agricultural practice was made possible by training about 36,000 farmers, attending special winter courses. As in the previous year, the expenditure was fully recovered by the results obtained.

The data obtained from various places shew that, when vernalized and unvernallized seeds were sown simultaneously, vernalized seeds produced seedlings earlier on the average by 2-4 days, a distinct advantage under the conditions of the region. Vernalization also produced thicker stands. According to data received from 558 collective farms, the number of plants per square metre was 307 on vernalized wheat plots and 270 on the unvernallized plots, and 324 and 292 respectively on oat sowings. This increase in the thickness of sowings is explained by the higher energy of sprouting of vernalized seeds. Data received from the Kolhoz "12 Oktjabrja" of the Sergiyevsk district shew that on the 4th day of sprouting 63 per cent of vernalized seeds and only 19 per cent of the unvernallized had germinated. The thicker stand, which was maintained throughout the vegetative season, reduced weed growth. Vernalization stimulated root development, and better rooting leads to a better development of green parts. At harvest vernalized plants were on the average 9.5 cm. taller. A better accumulation of dry matter is shewn also

by examination of sowings in the Sergiyevsk district on June 1st, the average height of vernalized and unvernallized plants being 31 cms. and 30.2 cms. respectively, and the weight of dry matter 102 gm. and 89 gm. Moreover, in the Koshkino district the number of plants per square metre which produced ears was greater on the vernalized than on the unvernallized sowings; only 10.2 per cent of the vernalized plants were without ears, whereas 15 per cent of the unvernallized plants produced no ear.

The main advantage of vernalization was however to be seen in earlier earing. Examination made on sowings of vernalized wheats (*Lutescens* 062, "N.O.E.", and *Caesium* 111) shewed that, on the average for 57 kolhozes, vernalized sowings began earing two and a half days earlier. The acceleration varied from nil (7 examples), one day (3 examples), three to four days (25 examples), five days (15 examples), to five days and over (7 examples). In most cases accelerated earing was due to earlier seedling emergence, hardly any direct influence of vernalization being reported, for the varieties used were of themselves early. Vernalization also increased the yield of wheat. In 139 kolhozes the grain yield of vernalized sowings was increased by 18.2 per cent. At the Kolhoz "12 Oktjabrja" the following average grain yields per ha. from vernalized and unvernallized sowings were obtained (vernalized given first in each case):

Extra early (April 14) 7.27 and 5.58. *Early* (April 24) 7.68 and 5.56.

Late (May 3) 5.45 and 4.24.

Thus, the effect of vernalization was higher in early sowings. However, the wide application of extra-early sowing of vernalized seeds cannot yet be recommended, for in the Kolhoz "Sila Mašiny" vernalized sowings made on April 18 with subsequent covering on April 22—25 yielded 5.90 centner per ha., whereas unvernallized sowings on the same date gave 6.47 centner per ha. It was noted that the vernalized seed had sprouted strongly and that their seedlings became yellow before covering.

Vernalized sowings developed under different conditions and consequently the effect varied. Vernalization had a greater effect in localities suffering from drought, e.g. in 24 kolhozes situated in dry districts, there was a recorded increase in grain yield of 28.6 per cent, as compared with 17 to 18 per cent in other kolhozes. Vernalization also improved the quality of the wheat grain.

The yield of oats was increased by 22 per cent (in 10 kolhozes) and the yield of millet in the Kolhoz "12 Oktjabrja" was raised from 9.50 to 13.59 centner per ha. Reports from 26 kolhozes shew that the average increase in the yield of millet was 1.80 centner per ha.

Vernalization of the potato in the Central Volga Region was tested for the first time. Although full reports are not yet available, examination in spring has shewn that vernalization is also highly effective in this crop. In the Buguruslan district on May 20 vernalized plants were 11 cm. higher than the unvernallized. At the Vyrypaev Station on July 3, the tuber yield of vernalized and unvernallized sowings was 80 and 30 centners per ha. respectively. Thus, vernalization produced an increased tuber yield and an acceleration of one month. The failure of the vernalization of potato reported from Kolhoz "Sila Mašiny" shewed that the threading of tubers on a string, as recommended in the instructions for vernalization, with or without disinfection by formalin, cannot be recommended owing to excessive rotting. The spreading of tubers in layers appears to be safer.

The application of vernalization was, of course, accompanied by occasional failures, but their number is small. The main cause of these failures in the majority of cases was deviation from the official instructions. On the whole, however, summarizing the results of 1934, the authors note that vernalization gave about 500,000 centners of additional grain of high quality, and that the agricultural application of vernalization has great prospects.

Kostov 69.**Cereals and flax.**

The collection of oats in the U.S.S.R. Institute of Plant Industry comprises 8,000 specimens; 1,100 of these were vernalized in Detskoe Selo in 1933. The reaction varied from good to nil. Some specimens showed retarded development after vernalization. Abyssinian oats, on the whole, reacted well. *A. strigosa* from Spain was represented by two specimens, one of which reacted well, and the other not at all. This and similar observations lead to the conclusion that specimens of the same species and derived from the same geographical region may give a different reaction, or, generally speaking, different genotypes react differently, irrespective of their place of origin. Among cultivated varieties, the following react well: Loitevickii, Heine, Kirsch, Weselen, Flandrian, French awnless, *A. byzantina* var. *fulgum*, and others. In 1934 it was proposed to vernalize 3,500 specimens from the same collection and to sow them in three different geographical localities of U.S.S.R. The method used in the present experiment was as follows: sprouting seed was chilled for 20 days at 4°C. The physiologist in charge of the experiment considers that many of the non-reacting oats would have reacted under different conditions of vernalization and also explains negative results by the appearance of mould on the seed and unfavourable conditions at the time of sowing.

Of 160 specimens of vernalized flax, only 2 - 3 gave a weak reaction, while others showed no response. The physiologist considers that favourable conditions for flax have not yet been found.

Of 3,830 specimens of vernalized barley, all forms eared and flowered, while in the control, none of the winter and alternative varieties showed any traces of earing. The duration of vernalization in barley was 35 days at 4°C.

Mednis 77.**Natural vernalization: Rye.**

Ultra-early sowings were made of a number of crops, including winter rye, which was sown, unvernallized, on April 15 1933 at the Jaroslav station and left then uncovered. The rye came into the shooting stage at the end of May and into ear only 15-18 days after autumn sown rye. It was harvested on 14th September and gave one centner grain and one centner straw per ha.

The possibility of obtaining a crop at all was due to the early sowing and germination of the grain uncovered on the surface of the soil. The average temperature for the first ten days of April was + 2.8°C., for the second ten days + 4.6° and for the third + 5.5°C. and only three days were below 0°C., -2.90°C. being the lowest; the yields would have been still better therefore had the sowing been done at the beginning of April.

In sowings at various seasons it is possible to study the mechanism of the conversion of plants from annual to biennial or perennial, or in the opposite direction.

No technique has yet been elaborated for vernalizing biennial crops such as turnips, sugar beet, chicory, etc., but winter sowing often leads to bolting and seed formation in the first year. It is of interest to know what is the value and amount of this seed and what would be the yield of the plants produced from such seed.

Ivchenko and Vacenko 64.**Wheat and Barley.**

Experiments were made in 1933 with seed of the cross *Triticum durum* var *Reichenbachii* 0843 × *T. durum* var. *melanopus* 037 and seed of the variety Černouska 069, harvested at the middle of the wax-ripe stage. Seed gathered at this stage germinated immediately without a period of rest. On the 4th August, after drying in the ear, later found to be unnecessary, they were germinated in the laboratory and on the second day placed in the ice chest for vernalization. The vernalized seed was sown in boxes on 16th August and came up on the 19th. One lot was

treated with supplementary illumination by one 500 W. lamp per square metre during the night from 23rd August for 18 days in order to ensure the normal completion of the photo-stage. In 1932 barley seed was sown in pots and chilled for seven days (by Safonov). Pots were then kept under natural conditions. Grain was produced at the end of September. In 1933 barley was vernalized before sowing in the open but no yield was obtained because of insect attacks. It is concluded that two yields of barley in one year can be obtained as a result of pre-sowing vernalization alone. The other half was grown outside in natural illumination. On 23rd September the plants receiving additional light were in ear and those under natural conditions were still in the tillering stage. Flowering began on 30th September and the plots were taken into the laboratory where the temperature of 20°C. necessary for anthesis was maintained. Flowering was completed in 7 - 10 days and fully matured grains were obtained on 5th December, whereas the un-illuminated plants had still not eared.

The weather conditions were not as favourable as in average years and the first sowing was at least ten days later than usual, therefore the success in normal years should be still more pronounced.

Popova 81.

Barley.

Experiments with vernalization were made by the author in the Kuban district with winter forms of local selections (Kruglik 024, 010 and 037) and foreign varieties (Mammoth German, and 0803 of the Dnepropetrovsk Sta.) and with hardy spring forms such as Kruglik 021, hybrid forms between local fodder strains and brewing barleys (Kruglik G-59, G-36, G-9 and G-17) and Swan-Neck of the Svalöf Station.

Preparation of seeds for vernalization and vernalization were made according to Lysenko's instructions (1932); in order to bring to the required state of moisture, 33 parts of water were added to every 100 parts of seeds at a temperature of 15° to 17°C., and the seed chilled at a temperature of +2°C. (in order to establish the optimum duration) for 17, 20 and 25 days for an early sowing (April 4), and for 35 days for a late sowing (April 15).

Vernalized sowings produced earlier seedlings (2 days on the average), which under the local short and dry spring could utilize the better conditions of moisture. Another positive influence of pre-sowing treatment can be seen from Table 16 which summarizes some results of 25 days of vernalization.

Table 16.

Name of variety.				Date of earing.		Date of ripening.	
				Vernalized	Control	Vernalized	Control
Kruglik 021	} Spring varieties	..	..	June 2	June 8	July 9	July 9
Kruglik G-58		..	..	" 6	" 7	" 12	" 26
Kruglik G-9		..	..	" 10	" 20	" 12	" 19
Kruglik G-36	..	..	..	" 4	" 8	" 6	" 9
Kruglik G-17	..	..	..	" 10	" 17	" 9	" 12
Swan Neck	..	..	..				
Mammoth German	} Winter varieties	..	..	" 2	—	" 4	—
Kruglik 010		..	..	" 15	—	" 20	—
Kruglik 024		..	..	" 16	—	" 20	—
Kruglik 037		..	..	" 14	—	" 12	—

Different varieties responded differently to the pre-sowing vernalization and in this respect the following three groups can virtually be recognized, namely, (1) earing

is considerably earlier but ripening is almost or quite simultaneous with the control, e.g. Kruglik 021; (2) earlier earing brings about early ripening, although less early than for instance, Kruglik G-9; (3) somewhat earlier earing brings about considerably earlier ripening, for instance Kruglik G-58.

Earlier earing and ripening enabled the vernalized plants to escape the adverse conditions of summer drought with the result that grain and straw yields were considerably increased; the external appearance of vernalized plants was considerably better than the control, as can be seen from Table 17, which summarizes some quantitative characters and the yield of some of the varieties vernalized for 25 days.

Table 17.

Name of variety.		Number of stems.		Average height of plants in cm.	Length of head in cm.	Spikelets per head.	Grains per head.	Grain yield on 100 plants in.		1000 grain weight in gm.
		total.	fertile					gm.	per cent	
Kruglik 021	{ vernalized	6.1	3.7	69	7	19	32	303	180	46.5
	{ control	4.8	2.7	65	6.4	17	30	167	100	39.5
Kruglik G-58	{ vernalized	4.0	3.0	81	8	21	15	300	125	52.0
	{ control	4.0	3.2	69	9	18	13	239	100	49.0
Kruglik G-9	{ vernalized	6.7	3.7	83	9	22	22	296	302	48.0
	{ control	6.4	2.3	70	8	22	17	98	100	47.0
Kruglik G-17	{ vernalized	5.6	4	73	10	23	18	163	603	44
	{ control	3.0	2	33	4	10	12	27	100	40
Kruglik 024	vernalized	5	3	69	8	—	34	300	99*	34
Kruglik 037	vernalized	5	2.2	76	6	—	30	266	87*	36
Kruglik 010	vernalized	2	1.8	69	6	—	22	221	72*	34
Mammoth German	vernalized	8	3.5	72	8	—	39	415	133*	38

*As compared with Kruglik 021 whose grain yield when vernalized is taken as 100.

Table 17 shews that the above-mentioned groups were connected with their productivity, namely, the productivity of the first group is considerably increased, (to 180 per cent in Kruglik 021); the yield of the second group is still higher, (302 per cent in Kruglik G-9) and the yield of the third group is also increased (225 per cent in Kruglik G-58). There is, however, a fourth group which shews only a slight acceleration in development, while the yield differs little from the control, (by 4 per cent in Kruglik 036). It is obvious that vernalization of such varieties is not practicable. On the whole, seed yield is mostly dependent upon the time of earing, for through an early earing the plants find better conditions for their development. Table 17 shews that all winter varieties when vernalized and sown in spring eared and that their yield, in some cases, was even superior to that of vernalized spring varieties. In this respect Mammoth German was particularly outstanding. When sown in autumn this variety produces a small yield owing to its low hardiness, but when vernalized it is much superior to any other spring variety in respect of yield and earliness. The absolute weight of its seed, however, is somewhat inferior to that of spring forms.

The experiments shew that the greatest effect was obtained by vernalization for 25 days. Thus, for instance, if the yield obtained through 25 days' vernaliza-

tion be taken as 100, the yield obtained in Kruglik 021 through vernalization for 20, 17 and 0 days was 64, 50 and 55 respectively and in Kruglik G-17, 49, 41 and 16. The data for 35 days vernalization were not available, and it is quite possible that 25 days vernalization is not the optimum for all the varieties.

In some varieties (Kruglik 021 and Kruglik G-58) the protein content of grains is somewhat increased whereas in some others (Swan-Neck, Kruglik G-36 and G-9) it is reduced. If further investigations confirm the possibility of increasing the protein content by pre-sowing treatment, this can be used in the selection of varieties for feeding and brewing.

The drying of seeds after vernalization does not influence germinating capacity; this is of great practical significance, for it enables plant breeders to store (in dry granaries), or to send away the dried vernalized seeds long before their sowing date.

Thus, on the whole this preliminary experiment confirms the applicability and efficiency of vernalization of barley under the conditions of the Kuban district.

Lysenko 73.

Millet.

Investigations on the phasic development of plants now make it possible to suggest a practical method of vernalizing millet. Water should be added at the rate of 26 parts per 100 parts of seed (by weight). Millet seeds generally absorb water very slowly and it is therefore recommended that small amounts (200-500 kg.) should be moistened in barrels or troughs. When all the water applied has been absorbed the seeds should be spread in layers sufficiently deep to ensure that a temperature of 20-25°C. will be maintained within the layer. The optimum thickness is usually 10 cm. Under these conditions about 2 to 3 per cent of the seeds begin to sprout in 2 to 3 days and the percentage rises to 5 to 10 per cent in 5 to 7 days. This percentage of sprouted seeds indicates that the moisture in the seeds is correct and that vernalization is progressing normally. To complete vernalization the seeds should be kept under these conditions for 5 to 7 days. Neither light nor darkness interferes with the completion of the first stage; it was found however that seeds artificially covered during daylight shew a reduced germination.

When the first stage has been completed in the seeds, the second stage can begin if the favourable conditions, namely, darkness, a temperature of 20-25°C. and humidity are present. When vernalized seeds are sown (using the normal depth of seeding), they find these conditions in the soil and therefore after sowing the second stage commences immediately and will be completed before the emergence of seedlings, i.e. during the first 5 to 7 days. This is not so with unvernallized seeds, for after having been sown, i.e. during the first 5 to 7 days, the second stage cannot even be commenced in spite of the optimum conditions in the soil, since it is essential that the first stage must be completed. For this reason unvernallized seeds are unable to make use of the essential factor of darkness given them by the normal depth of seeding before the emergence of their seedlings, with the result that in order to complete the second stage after the emergence of seedlings the plants use only the night hours and their reproduction is therefore delayed or even prevented. A prolongation of darkness by artificially covering the green plants would have an adverse influence as light is required for photosynthesis. Thus the pre-sowing completion of the second stage although possible is unnecessary, for the conditions required tend to reduce germinability through mould attack, and the pre-sowing completion of the first stage alone can give the same effect.

The beginning of pre-sowing treatment should be arranged with reference to seasonal conditions. In districts with wet soil it should be commenced at the time of cutting the preceding crop; in more arid districts it should not be commenced before a good rainfall; immediately after the rain, if not later than July 10, the

preparation of seeds for vernalization and of the soil for sowing (harrowing) should be begun.

If for any reason vernalized seeds are not sown they must be dried and can be used in the same way as unvernallized dry seeds, for the nutritive quality of the vernalized seeds is not lowered by the treatment.

Ukrainskii 91.

Rice.

Observations have been made on the light and heat requirements of rice varieties, combined with other factors. Varieties have been found which require from 90 to 120 days free from frost for their development and a total sum of 2,160-2,700° of heat, according to variety. The actual amount of heat required varies with the illumination from the point of view of photosynthesis. Thus an early variety that with a given total of heat will not ripen in southern regions may in more northerly zones ripen with the same heat total, because of the greater length of daily illumination.

Experiments are described in which the reduction of the length of day to 12 hours accelerated the exertion of the panicle by 7 days and the beginning of flowering by 6 days, shewing that rice is a short-day plant. For this reason it cannot be cultivated further north than 45-55°. The time of flowering is also influenced by the hydrogen ion concentration and the fertility of the soil.

HERBAGE AND FORAGE CROPS.

Travin 89.

Forage crops.

Preliminary investigations on the vernalization of annual and perennial herbage and forage plants dealt with *Trifolium pratense*, *Medicago sativa*, *Melilotus alba*, *Onobrychis*, Sudan grass, sorghum, *Dactylis glomerata*, *Festuca pratensis* and *Vicia* spp. In the case of all species except *Vicia sativa* and *V. villosa*, chilling did not accelerate reproduction, although it had a marked effect on vegetative development, sowings of *Dactylis glomerata* made with germinated seed chilled for two months shewing an increase of 61 per cent in green mass. Preliminary results with the *Vicia* spp. suggest that chilling reduces the vegetative period and increases the seed yield, but these results require confirmation.

Čepikova 50 and 51.

Perennial herbage plants.

The absence of information on the vernalization of perennial herbage plants induced the author to begin a tentative experiment in 1933 at the Institute of Fodders, Kachalkino, on the proper doses of the appropriate factors for vernalization of plants of this type. The scheme of experiments was necessarily complicated since two variants of temperature and humidity during vernalization and three variants of duration of chilling had to be included; it was also considered advisable to introduce the light factor, important for the second (photo-) stage. The photo-factors, namely, continuous light (200 candlepower at a distance of 0.5 m.), or continuous darkness, or normal seasonal day were given continuously during five days subsequent to the completion of chilling. Experiments were made with *Alopecurus pratensis* (meadow foxtail), *Phleum pratense* (timothy), double and single cut red clovers (*Trifolium pratense*) and turnips, to investigate the effect of pre-sowing vernalization on the progress of the vegetative phases and the accumulation of forage yield.

Further information regarding the arrangement of the experiment and the different variants used are given in Table 18 and elsewhere in this review.

Table 18.

Plant	Duration			Temperature		Humidity		Light		
	1	2	3	1	2	1	2	1	2	3
<i>Alopecurus pratensis</i> 76 pots + 2 wet control ..	20	30	40	0 to 3°	+5 to 8°	100	200	Darkness	Light	Normal day
<i>Phleum pratense</i> . 76 pots + 2 wet control ..	15	25	35	3°	8°	70	100	Darkness	Light	Normal day.
<i>Trifolium pratense</i> . Double cut .. 74 pots + 2 dry control ..	5	10	20	+5°	+10 to 12°	60	100	Darkness	Light	Normal day.
<i>Trifolium pratense</i> Single cut. 28 pots + 2 dry control ..	20	30	40	+3°	+8°	60	100	Darkness	Light	Normal day.

[Wet control=seed soaked for 24 hours before sowing.

Dry control=seed sown dry.]

Column 1—Duration = Duration of chilling in days.

„ 2—Temperature = Temperature of vernalization in °C.

„ 3—Humidity = Humidity in percentage of weight of seed.

„ 4—Light = Type of photo-factor given continuously for 5 days subsequent to chilling.

Seeds were vernalized according to Lysenko's scheme. Vernalized seeds were sown in pots 30 × 30 cm. in size (25 per pot) with two replicates. After germination was completed, only 8 plants were left in each plot. In order to avoid the stimulative effect of manuring, only 0.3 grm. of nitrogen, phosphorus and potash were given to each 7 kg. of soil. Nitrogen was not given to legumes. The experiment was made at 100 per cent humidity with the forage plants and 60 per cent humidity with the turnips.

Owing to the complicated nature of the experiment, it is possible to refer only to the main conclusions drawn for each plant separately. (See also Tables 19 to 21.)

Alopecurus pratensis 1409 (Krasnye Zori Station), vernalized April 5 to May 14 (according to duration required); light treatment May 14 to 19; sown (vernalized and unvernalized) May 19; harvested (unvernalized at tillering stage) August 11.

Observations:

(1) Duration of Chilling.

(a) The onset of the vegetative phases (tillering, shooting, emergence and flowering) was increasingly early with increases in the duration of chilling, acceleration being about 10 to 14 days. The control continued tillering throughout the experiment.

(b) Maximum height was attained by plants which received 40 days chilling;

height decreased with shortening of chilling period, although even 20 days chilling produced plants almost double the height of the controls. The same result was found in number of panicles (absent in control). Vigour of tillering (number of tillers), lowest in the control, increased as the chilling period was reduced to 20 days. Consequently the forage yield (air-dry weight) was about 50 per cent higher from vernalized plants after 40 days chilling than from the controls.

(2) *Temperature.*

3°C. as compared with 5° to 8°C. produced earlier ear emergence (by 8 to 9 days) and flowering, and greater height.

(3) *Humidity.*

No conspicuous responses were detected.

(4) *Light.*

(a) Although additional light or darkness had little effect, yet a delay (never exceeding 5 days) was found in certain variants after additional light.

(b) Additional darkness produced superiority in height, tillering and flowering, but variations in light had generally little effect.

General conclusions for meadow foxtail.

Meadow foxtail thus shews a marked response to duration of chilling, less to temperature variations, still less to changes in light and practically none to variations in humidity during vernalization.

Phleum pratense 362-13 (Krasnye Zori Station). Vernalized April 5 to May 10 (according to duration); light treatment May 10 to 16; sown (with control) May 16; harvested at late phase of flowering August 17.

Observations.

(1) *Duration of chilling.*

(a) As little response to variation was noted, the vegetative phases progress simultaneously; acceleration in the vegetative phases, particularly marked for flowering, was 14 to 16 days as compared with the control.

(b) Increasing duration produced a slight increase in height, tillering, number of panicles and yield.

(2) *Temperature.*

The best temperature was 3°C. as all variants and all phases were 4 to 5 days earlier than with 8°C. and 14 days earlier than control. 3°C. is also best for height, tillering, number of panicles and yield.

(3) *Humidity.*

70 per cent humidity is best, as all vegetative phases were 1 to 3 days earlier than with 100 per cent humidity.

(4) *Light.*

(a) All variants receiving additional darkness shewed an acceleration of never more than 5 days in the onset of the vegetative phases as compared with those receiving either additional light or no additional darkness. The latter two variants were similar in their development.

(b) Superiority in height and tillering was obtained with plants receiving neither additional light nor darkness. Most panicles and highest forage yield were produced by shaded variants; the difference between the other two variants in these respects was negligible.

General conclusions for timothy.

Timothy thus shews a marked response to temperature, but little to the other factors.

Trifolium pratense: double cut, 2051 (Krasnye Zori Station). Vernalized April 9 to May 1 (according to duration); light treatment May 1 to 6; vernalized and control harvested September 2. The vernalized plants were harvested before seeds were completely ripe owing to commencement of cool, rainy weather; control plants were at the stage of flower buds.

Observations.

(1) Duration of chilling.

(a) The earliest commencement of the vegetative phases (appearance of first compound leaf, stem formation, budding and flowering) was obtained with 10 days chilling; 20 days or 5 days retarded development.

(b) The same is true for height, tillering, number of heads and nodes and forage yield.

(2) Temperature.

(a) Chilling at 10° to 12°C. caused the vegetative phases to be 4 to 5 days earlier than in variants at 5°C. and 12 to 14 days earlier than in control.

(b) Height, number of heads, stem and nodes and forage yield are favoured by this temperature.

(3) Humidity.

The influence of variation in this factor was not recorded, but in certain cases 60 per cent appeared to be superior.

(4) Light.

Plants receiving additional darkness passed more rapidly through all vegetative phases, produced more stems, nodes and heads and a higher forage yield than variants which had not received darkness or received additional light.

General conclusions for double cut red clover.

The plants responded most markedly to duration of chilling, somewhat less to variation in temperature, still less to light and humidity. The cause of the negative effect of 20 days chilling requires further laboratory study.

Trifolium pratense: single cut, 1053 (Krasnye Zori Station). Vernalized April 4 to May 14, according to duration required; vernalized and control seeds sown in pots on May 14; vernalized (at flowering) and control (before flowering) harvested September 13.

Chilling for 40 days was best, followed by the 20-day period; the somewhat inferior effect of 30 days chilling cannot be explained, but may be due to an unsatisfactory combination of factors.

Flowering and all vegetative phases began 8 to 10 days earlier in vernalized variants than in the control.

Chilling at 3°C. had a greater influence on vegetative phases, morphological characters and forage yield than at 8°C.

The divergences observed between parallel pots and the heavy mortality of plants have compelled the author to regard the data as of doubtful accuracy and the conclusions as preliminary.

Fodder turnips.

These were treated for 30 and 40 days respectively at temperatures and humidity which are not stated. Severe attacks of cabbage fly made it impossible to complete the experiment. However, early records of seed germination and vegetative phases (progress of the phases from formation of cotyledons until the formation of the first pairs of proper leaves) which shewed an acceleration of 4 to 5 days in the vernalized variants, suggest the value of the treatment in this crop.

Zerling and Čepikova 94 and 95.**Significance of factors in first year.**

The discussion concerns that part of the foregoing experiment which involves only variants of duration, temperature and humidity in the first stage. Results summarized in Tables 19 to 21 shew that all the plants studied accelerated their development to a varying extent, the more perennial the plant the stronger being the effect of vernalization. Thus, for instance, control meadow foxtail and single cut clover did not form buds or flowers in the first year, whereas the vernalized variants of these plants flowered; double-cut clover and timothy when vernalized not only flowered earlier, but also increased the number of heads and panicles as compared with the control plants.

These data contradict the opinion as to the antagonism existing between vegetative and reproductive development, for vernalization produced both accelerated development and an increase in the number of reproductive organs and in yield of vegetative parts. The significance of the individual factors varies for different plants. Thus the dominant factor for meadow foxtail is the duration of vernalization; the duration has also a marked effect on double-cut clover, but a higher temperature during vernalization shortens the vegetative period; the vegetative period of single

Table 19. Vernalization of *Trifolium pratense* in 1933.

Vernalizing factor.			Single cut variety.			
Humidity.	Tempera- ture.	Duration in days.	Length of vegetative period in days.	Heads formed.		
				number.	per cent.	
60 per cent.	3°C.	20	92	6	100	
		40	90	9	150	
	8°C.	20	96	6	100	
		40	95	11	183	
100 per cent.	3°C.	20	100	7	117	
		40	98	12	200	
	8°C.	20	103	7	117	
		40	—	—	—	
60 per cent.	5°C.	5	86	7	100	
		10	85	13	186	
		20	—	4	59	
	10° to 12°C.	5	83	7	100	
		10	83	11	159	
		20	101	4	59	
	100 per cent.	5°C.	5	86	6	86
			10	88	3	114
20			—	2	27	
10° to 12°C.		5	80	7	100	
		10	83	13	186	
		20	101	4	59	

Table 20. Vernalization of *Alopecurus pratensis*.

Vernalizing factors.			First year—1933.			Second year—1934.		
Humidity	Tempera- ture.	Dura- tion in days	Length of vegetative period in days.	Panicles produced.		Length of vegetative period in days.	Panicles produced.	
				num- ber.	per cent		num- ber	per cent
100 per cent	0 °to 3°C.	20	70	4	100	64	21	161
		30	63	17	425	61	23	177
		40	60	30	750	58	26	200
	5° to 8°C.	20	70	3	75	64	19	146
		30	67	6	150	62	21	161
		40	66	11	275	60	23	177
200 per cent	0° to 3°C.	20	70	7	175	65	19	146
		30	64	9	225	61	22	170
		40	61	21	525	59	25	192
	5° to 8°C.	20	71	2	50	65	21	161
		30	66	11	275	63	20	154
		40	62	18	450	60	30	230
Control	seed dry		No flowering			75	13	100
	soaked for 24 hours					74	14	107

Table 21. Vernalization of *Phleum pratense*.

Vernalizing factors.			First year—1933.			Second year—1934.		
Humidity.	Temperature.	Duration in days	Length of vegetative period in days.	Panicles produced.		Length of vegetative period in days.	Panicles produced.	
				num-ber.	per cent.		num-ber.	per cent.
70 per cent.	3°C.	15	72	32	168	55	35	194
		25	73	32	168	57	36	200
		35	72	35	184	53	34	190
	8°C.	15	78	29	153	60	30	106
		25	77	31	163	59	29	161
		35	78	32	168	60	31	171
100 per cent.	3°C.	15	74	31	163	56	34	190
		25	74	33	173	55	36	200
		35	75	33	173	53	35	194
	8°C.	15	79	30	158	61	31	171
		25	78	30	158	59	32	177
		35	78	31	163	60	31	171
	Control	Seed sown dry.	86	19	100	71	18	100
		Seed soaked for 24 hours.	84	23	121	72	18	100

cut clover is affected by all three factors. The above results indicate that the biological properties of plants form one of the decisive aspects in the response of the plants to variation in the vernalizing factors and consequently in the whole development of the plant. Experimental data show also that in most cases the duration of vernalization is the dominant factor; with a gradual prolongation, the rate of development is gradually increased. This shows that vernalization progresses during a certain period and that the accumulation of all changes associated with this process in the plant causes corresponding changes in the rate of development.

As regards the number of reproductive organs, the significance of individual factors for different plants is almost the same, the dominant factor (duration of vernalization) being the same for all the plants studied. The biological properties of plants have less effect, therefore, on the vigour of growth than on the rate of development, and the duration of vernalization is one of the main factors influencing the number of reproductive organs and thus the size of the seed yield.

Čepikova 60.

After-effect in second year.

Results obtained in 1934 showed that the effect of the vernalizing factors used in 1933 is still to be seen in the behaviour of two-year-old plants. In the second year of the experiment their development was considerably accelerated, the treated plants producing ears 12 to 14 days earlier and flowering 9 to 10 days earlier than the control. An increase in the number of heads, panicles, and in total yield was also observed. The behaviour of *Phleum pratense* in 1934, which eared and flowered 12 to 14 days earlier than the control in the first year, and of *Alopecurus pratensis* in the same year is shown in Tables 20 and 21. Moreover, all the experimental plants showed more regular development and flowering in their second year, the flowering period being 7 to 9 days as compared with 15 to 17 days in the controls.

The relative significance of individual factors was the same in 1934 as in 1933 and the retarded flowering of the double-cut clover variant vernalized for 20 days in 1933 was again recorded. By comparing the 1934 results with those for 1933, it can be seen that, although the various factors are in the same order of importance, *Phleum pratense* has shown a much greater response to vernalization in the second year.

Zerling and Čepikova 96.

Reversibility of vernalizing process.

The authors stress the view that vernalization is a gradual process, not a series of abrupt changes as postulated by Lysenko. Examples are quoted from their own and other writers of reversal of vernalization if continued beyond the critical stage.

The results of experiments with red clover (*Trifolium pratense*) are of particular interest in the fact that reversal of the effect of vernalization has been produced by extending the duration to 20 days (see Table 19.)

Koreiša 66.

First and second stage.

Although the application of methods of pre-sowing treatment to seeds of perennial plants is restricted by the fact that the influence is probably confined to the first year's growth, yet the knowledge as to the character of the stages of development in perennial plants is of great significance, as it enables the breeder (a) to select for mixtures plants with varying rates of accumulation of dry matter as affected by the character of the stage, (b) to accelerate and increase seed production, and (c) to investigate changes in the feeding qualities of the crop in connexion with the completion of various stages.

As a result of investigations on the character of the completion of the thermo-stage at the Department of Herbage Plants of the Institute of Plant Breeding and Genetics, Odessa with most of the plants cultivated in the steppes of the Ukraine,

two groups of plants were established, namely, winter perennials with a "long" thermo-stage requiring low temperature, and spring perennials with a "short" thermo-stage. The "long" thermo-stage of the first group, which includes biennial sweet clovers, single-cut sainfoins, timothy, ryegrass and *Poa*, prevents these plants from flowering and producing seeds when sown in spring. On the other hand the plants of the second group, which includes double-cut sainfoins, Transcaucasian sainfoins, cultivated lucerne, yellow lucerne, *Bromus* spp. and *Agropyrum tenerum*, flower and bear fruit when sown in spring.

The character of the photo-stage has been investigated only on various lucernes of different geographical origin; the length of the second stage (i.e. the duration of darkness required for its completion) decreases from north to south and is associated with an almost parallel change of the rosette from prostrate to erect, and a fall in winterhardiness. Thus, as compared with the same varieties grown under a short 10-hour day, the length of the photo-stage was prolonged under the natural seasonal day in northern strains which have the prostrate type of rosette and high winterhardiness, by 2-5 days; in forms with the semi-prostrate type of rosette and lower winterhardiness, by 2-3 days; and in non-hardy lucernes with the erect type of rosette, by one day. This correlation between the length of the photo-stage, winterhardiness and the type of rosette can throw some light upon the origin of winter-hardy races.

Kostov 67. Epifanov 54.

Vetch and forage crops.

Inspection made in 1934 by the members of the Institute of Plant Industry Leningrad in 265 kolхозes of the Gorki, Ivanovsk Industrial and Moscow regions on vernalized agricultural sowings of wheat, oats and barley and on experimental sowings of vernalized vetch and millet shewed that the vernalized sowings were on the average 6 to 7 days earlier in maturing. All vernalized crops shewed an increased seed yield, the cereals 1 to 3 centner per ha., and the vetch and millet 2 to 4 centner per ha. Thus vernalization is as efficient in the northern regions as in the south. Further experiments should, however, be made on the vernalization of millet and vetch, which usually cannot ripen seed in the north. The information available regarding millet which is usually sown late in June shewed that the crop can ripen there before the autumn cold only when sown vernalized. Of particular importance are experiments on the vernalization of vetch for which late varieties are recommended. The technique for this crop is as follows:—

The seeds after being cleaned should be brought to an optimum moisture by adding 70 kg. of water to every 100 kg. of seeds with a normal (14 per cent) water content. For this purpose seeds are placed in a container to which the water is added and they are well stirred every 2-3 hours to ensure uniform moistening. When the water has been entirely and uniformly absorbed the seeds are placed in a layer 20 to 25 cm. thick, covered and kept at a temperature of 10 to 15°C. until the seed coat is burst on 5 to 10 per cent of the seeds. This provision of adequate moisture is very important as the vernalizing process will not progress in seed with deficient moisture. The moisture in the seeds should be such as to permit very slow sprouting. If the seeds in the layer do not commence to sprout in 1 to 2 days at a temperature of 10°C., 3 to 5 kg. of water should be added to every 100 kg. of seeds, and the seeds well stirred. If sprouting proceeds too rapidly the moisture content should be reduced by stirring. When the seed coats of 5 to 10 per cent of the seeds have burst, the temperature should be lowered to 5° to 8°C. according to Epifanov and 8° to 10°C. according to Kostov and kept at that level for 10 days, when the vernalizing processes will be completed. The temperature in the seed layers should be carefully regulated throughout by decreasing or increasing the thickness of the seed layers.

Vernalized seeds should be sown not later than the usual date. If the time of sowing arrives before the vernalization is completed the seeds should be sown in an under-vernalized state. If vernalization has been completed before the time of sowing the seed layers should be made thinner and the seeds slightly dried.

Vernalized vetch can be sown alone or in mixtures. In the latter case the mixtures should be prepared the day before or on the actual day of sowing. Vernalized seeds are heavier and larger than unvernallized seeds and care should be taken to sow the same number of vernalized seeds per unit area as of the unvernallized seeds.

Zvanskiĭ and Spilevskii 97 and 98.

Winter rape.

A preliminary experiment was made in Minsk to vernalize dwarf rape, a winter plant in the warm and humid climate of that region. The pre-sowing chilling was done as follows: on March 20, 3 kg. of seed spread evenly on a piece of cardboard 1.5 sq. metres in size were watered and sprouted in the laboratory at a temperature of 14°C.; to maintain the humidity within the seed layer, the seeds were covered with filter paper which was watered twice daily. On March 23 it was found that only 43.67 per cent of the seed had sprouted to any extent. After that date germination was stopped; the seeds were placed in a gauze bag and sown in snow in the open. Owing to a thaw on April 8, the seeds were removed to a cellar and kept inside until April 23 when they were sown. The seed before sowing showed 88 per cent germination; vernalized seeds were quite sound without any trace of mould. Seedlings developed uniformly and vigorously and flower-bearing stems were formed at the beginning of June. It was then found that the percentage of plants bearing flowers was the same as the percentage of seed which had sprouted before the chilling treatment. This demonstrates the importance of obtaining the largest possible percentage of germinated seeds before the treatment by chilling. The vernalized plants flowered in July and August, their seeds being gathered gradually as they ripened. In spite of the somewhat primitive technique used in the experiment, the results were quite satisfactory. One kg. of seeds of winter rape when sown in spring produced 1 kg. of seed, a result which could not have been obtained without pre-sowing treatment.

COTTON.

Stets 87.

Cotton.

Experiments were conducted by the method recommended by the Ukrainian Breeding Institute, the air temperature however being 3-5°C. higher than that recommended (15-17°C.) and the soil temperature also being slightly too high.

Navrotskii and Ashmouni cottons were used, both experimental and control seeds being previously soaked for 1 to 2 days. Sowing was carried out on May 5th.

On May 18th observations were made on the seedlings, which showed that the vernalized plants were more vigorous, strong and healthy than the controls, being fresher, larger and denser, in the case of Navrotskii, but in Ashmouni little difference between the two was detectable. The speed of germination was greater in the treated plants, and the percentage germination was also higher.

In respect of density the vernalized seed gave results intermediate between the control and delinted seed.

From these results the author concludes that it is necessary to work out a method for vernalizing cotton for the conditions of Central Asia. He is also inclined to think that the repeated moistening and spreading during the process of vernalization, leading to a matting of the lint and fuzz, is largely responsible for the better germination of vernalized Navrotskii seed, owing to the better water absorbing capacity. This also accounts for the less pronounced effect observed in Ashmouni, with naked seeds.

Novikov 80.**Cotton.**

Yield increases have been obtained on all the vernalized cotton plots, some of which were of an area of 6 hectares and over. These yield increases were obtained even from cotton grown under the most favourable cultural conditions and are almost entirely to be observed in the first picking, i.e. before the beginning of the early frosts, and in many cases the length of the lint was also increased.

Some varieties after vernalization displayed a certain acceleration in the time at which the various developmental stages set in. Other varieties did not react at all, whilst still others reacted negatively to a 20 day treatment and positively to a 15 day treatment. Some varieties have even given varying effects in different experiments, shewing that the method requires further elaboration.

Civinskii 53.**Cotton.**

The technique of vernalization for cotton is described. Each variety must be treated with the proper conditions of temperature and moisture for the requisite length of time and the determination of this time, which may vary for each variety, has been one of the main difficulties. Richter however has found that vernalized embryos are coloured blue by methylene blue in buffer solutions of suitable pH, whilst un-vernalized embryos go pink. The iso-electric point is thus changed by vernalization and it is now possible to determine accurately when a seed has been correctly vernalized. The time required by four different cotton varieties was determined in 1933, the varieties being representative of both *Gossypium hirsutum* and *G. barbadense*. The seeds were treated for 5, 10, 15 and 20 days, with a control untreated. The treatment consisted in placing the seeds in glass jars at a temperature of 25 - 30°C, with an initial moisture of 80 per cent of the dry weight. The seeds were aired for an hour each day by spreading on the table. However, owing to the high degree of fungal attack and germination it was thought advisable to reduce the moisture to 60 per cent and the temperature to 20 - 25°C.

The treated and control seeds were sown together on April 25th, the control seeds having been moistened for 48 hours before sowing.

The longer periods of treatment depressed the germination, 20 days treatment depressing it by 46 - 69 per cent, 15 days by 11.4 to 13.7 per cent. The shorter treatments had no effect on germination and one variety, Acala 8517, was unaffected in germination even by the 20 days treatment.

The effects on the flower bud development were as follows :—

The variety Navrotskii was not accelerated in flower bud formation but even retarded by 5 days in the 20 day treatment; Acala 8517 only by 2 days in the 10 and 15 day treatments. Ashmouni gave an acceleration of three days in the 5 day treatment and Pima an acceleration of four days in the 15 day treatment. None of these differences is of any real significance.

The effect of the treatment seems to be not so much in an acceleration of the inception of the phases of development as in the more rapid completion of each phase. This is illustrated by the data for the time of 50 per cent maturity and for the yield of lint. Acala 8517 shewed an acceleration only in the 5 day and 10 day treatments yet there was an increment of yield in the first pick in the other treatments of 27.2 to 30.2 per cent. Pima shewed the same effect. This difference was mainly in the rapidity with which the fruits matured, for the total yield difference only amounted to 13 per cent, as shewn in Table 22. The Egyptian varieties are still doubtful: however Ashmouni was earlier in maturity in the 5 and 10 day treatments and gave a greater first pick, though the total yield of lint was not increased.

The most favourable periods of treatment are 10 - 15 days for Navrotskii, 15 - 20 days for Acala 8517, and 15 days for the Egyptians.

Pudovkina and Tašlanov 82.**Cotton.**

A variety test was carried out with promising American and Egyptian cottons, which were treated at a moisture content of 60 per cent for 13 days at 25 - 30°C. All varieties germinated 2 - 3 days earlier in the vernalized than in the control series; in the later stages the varieties differed in behaviour: the Egyptian varieties, which are late in maturity, shewed an acceleration in flowering and maturity of 5 - 11 days, whilst the earlier American varieties were hastened only by 4 days. Also within the Egyptian group the late varieties were more affected than the earlier ones. This relationship did not hold however for the varieties within the American group, and some of these were even retarded by the treatment.

The varieties that reacted most with regard to earliness of flowering and maturity also gave the greatest increase in yield from the first picking. This was most marked in the Egyptian varieties, where yield increases of 78 to 157 per cent were recorded in the latest varieties Maarad and Pima. The American varieties shewed much lower yield differences, Nos. 8427 and 8517 giving the most, and the yields of the other varieties were actually reduced. The total yields of lint were similar in every way except that the differences were less pronounced, since in the late varieties the second picking was reduced at the expense of the first. This in itself is an advantage, since it affects the quality of the product in favour of the vernalized series.

The lint length and ginning percentage both tended to be higher in the vernalized plants in the American cottons, whilst the Egyptians gave a slightly reduced lint length, though the ginning percentage was increased.

Table 22. Yield of Raw-Product in Grammes and per cent per Plant.

Variety.	Period of treatment in days.	First picking before the beginning of frosts		Total yield.	
		In grammes.	In percentage.	In grammes.	In percentage.
Navrotskii. ..	Control	66.4	100	87.6	100
	5 days	59.8	90.7	66.5	75.8
	10 "	57.3	86.5	74.3	84.7
	15 "	59.8	90.2	97.1	100.8
	20 "	82.1	124.8	139.3	159.0
Acala 8517 ..	Control	39.9	100	68.4	100
	5 days	54.1	136.0	72.5	106.0
	10 "	52.4	131.0	70.6	103.2
	15 "	51.9	130.2	76.6	112.1
	20 "	51.6	127.2	77.3	113.0
Ashmouni ..	Control	17.1	100.	37.7	100
	5 days	19.4	113.5	30.8	79.6
	10 "	17.9	104.7	31.2	82.8
	15 "	14.1	82.4	32.4	85.9
	20 "	15.2	88.9	38.7	102.6
Pima	Control	23.0	100	43.3	100
	5 days	24.5	106.4	35.6	82.2
	10 "	21.2	92.3	31.5	77.8
	15 "	26.9	117.0	43.3	100.0
	20 "	45.0	195.7	65.0	150.1

Tueva and Todorov 90.**Cotton.**

Further experiments were conducted in 1932-33 on early, mid-early and mid-late varieties of Upland cotton and a number of Egyptian varieties. The seeds were vernalized under the conditions indicated by Lysenko, for 10-11 days. The germination percentage of the treated seeds was somewhat below that of the control, but the early development was distinctly better in the treated seedlings, as was also the height of the plants at the end of May. There was no difference in the number of nodes and the height of insertion of the first sympodial branch was also not appreciably different in the treated and untreated plants. On the other hand the flowering was more uniform in certain varieties in the treated plants, as for instance in Navrotskiĭ and Ashmouni. The accelerations observed were generally between 3 and 4 days but amounted to 13 days for Navrotskiĭ and 9 days for Ashmouni. The differences in date of maturity were in many cases greater, amounting to 12 days in Ashmouni as compared with 9 for flowering.

In all pickings the vernalized plants gave an excess over the controls. In these experiments again the excess in the first picking was especially marked, particularly in the variety 8517. It is pointed out that the effect of the treatment on Navrotskiĭ is much more favourable than the 20 day treatment employed in earlier experiments.

A further experiment was designed to test the effect of keeping the seeds in a dried condition for 20 days after the end of vernalization. The dried seeds were sown on May 10 and the results shewed that the effects of vernalization had not been in any way impaired by keeping.

Ivanišin 61.**Cotton.**

The first stage in cotton vernalization is to moisten the seed to 80 per cent (57 litres water to 100 kg. cotton seed). The moistened seed is left in a heap, whereby the temperature in the heap rises to 23-25°C., under which conditions the seed is maintained for 15-20 days; every means, including drying, cooling, etc., is used to prevent the seeds germinating and to avoid the growth of moulds. Not more than 1-3 per cent of seeds must be allowed to germinate. After this treatment the seeds are sown in the ordinary way.

The results of the experiments of the three years 1932, 1933 and 1934 shew that after vernalization all the main developmental stages are accelerated; thus germination is accelerated by 2 to 14 days, flowering by 3 to 8 days and maturity by 4 to 15 days, as a result of which the yield and especially the production of lint is considerably increased. On May 2 1933 the vernalized seedlings sown on April 20 were more advanced than unvernallized seedlings sown both on April 20 and April 10. Yield differences of 2-3 centners per ha. in favour of the vernalized plants were also obtained in 1933.

Plots of 1 ha. in area were sown with vernalized and unvernallized seed in 1933 and 1934. In 1933, 44 per cent of the vernalized and only 19 per cent of the unvernallized plants had matured on October 9 and in the following year the date of maturity was September 9 for the vernalized and September 13 for the unvernallized, the yields in the two years being 11.1 and 8.2 centners per ha. respectively for the vernalized and 8.8 and 6.0 for the unvernallized. The effect was greater in 1933 which was a most unfavourable year for cotton in these new regions, whilst in 1934 the conditions were more favourable for natural vernalization.

Large-scale vernalized sowings on collective farms were made in 1932 on an area of 600 ha., the area being increased to 2,000 ha. in 1933 and 3,000 in 1934, control sowings being made in each case. The average increase in yield was from 0.3 to 2.5 centner per ha. and on one farm the vernalized sowings gave four times as much yield per ha. as the control. In most farms the vernalized seeds germinated more rapidly and flowering was in most cases similarly accelerated,

Not infrequent cases of failure in cotton vernalization are partly attributed to inadequate attention to the details of technique.

Taşlanov and Pudovkina 88.

Cotton.

Cotton vernalization is very simple ; the seeds are brought to a moisture content of 60 per cent of their absolute dry weight by three successive moistenings, placed in lots of 500 grm. in sacks which are arranged in a pile about half a metre high. They thus acquire by their own respiration a sufficiently high temperature to effect vernalization. The height of the pile is regulated according to the temperature, making it greater if an increase in temperature is required and vice versa, in such a way that a temperature of 13 to 23°C. is maintained during the first three days and 25 to 30°C. during the next thirteen. This is easily achieved when the temperature of the room is 13-20°C. The seeds are stirred two to three times a day during the whole process to prevent rotting.

Such vernalized seeds were sown on April 24, 1933, together with control seeds moistened for 48 hours before sowing. The treated seeds germinated uniformly, two to three days earlier than the controls. In all the Egyptian varieties there was also an acceleration of flowering and maturity, this being more pronounced in the late than the early varieties. Thus late varieties such as Maarad and Pima without vernalization gave less than 50 per cent maturity before the first frost on October 13, when the treated plants had all matured uniformly and even earlier than the earliest Egyptian variety, Ashmouni (1st to 4th October). An acceleration of 9 to 11 days was observed in two other varieties, Nos. 23 and 48.

The American varieties were not accelerated quite to the same extent and there was greater difference between varieties. Thus the variety 8427 was accelerated much more than 8517, whilst 8582 and Navrotskiï were even retarded. Again, however, the latest varieties reacted most.

Yield increases were observed in all the Egyptian varieties, especially the late varieties, Pima and Maarad, the effect being particularly evident in the yield of the first picking, where differences ranging from 27 to 150 per cent were obtained. Increased yields in the American varieties were shewn only in varieties 8427 and 8517, the others were either unchanged or reduced. In the American varieties, moreover, the proportion of the first to the second picking was also not changed.

The boll size, ginning percentage and lint length were unchanged in most varieties of both groups. An exception was afforded by the variety 36M which, though a relatively late form, gave a reduction in all these, associated with the greatest observed decrease in yield.

The method of vernalization is thus seen to be particularly favourable for the Egyptian varieties, but it is thought that by altering the technique it might be possible to get results also from the American varieties. It is recommended that for each region the variety giving the greatest reaction to vernalization should be chosen for cultivation and that variety tests with vernalized seed should be undertaken in each region. The method is also valuable in breeding, enabling the maximum rapidity of multiplication to be obtained, especially with Egyptian cottons.

Kostov 68.

Cotton.

In order to vernalize cotton it is necessary to subject the seed to the influence of the following factors : humidity, temperature, adequate air supply and covering the seed to prevent an excessive evaporation and to protect it from the penetration of light, the latter being essential only for Egyptian cotton.

It is advisable to moisten the seed four times during a 36 hour period, taking for this 57 or 52 parts (for the American and Egyptian cotton respectively) of water per 100 parts (by weight) of seed. The temperature of the water at soaking should be

about 20°C. Immediately after, the seed should be spread in a layer 30-50 cm. thick and carefully covered. The temperature of the seed in the layer should be maintained at 25-30°C. at which vernalization will occur. It is desirable that the embryo should just begin to develop, but it should not be allowed to pierce its seed coat. Seed germination should be controlled by the degree of humidity. It is advisable to maintain a humidity under which only 5 to 10 per cent of the treated seed will crack during the first five days of vernalization. If during the first 3-5 days of treatment (under 25 to 30°C) the seed does not begin to crack the humidity is inadequate. In order to ensure an adequate air supply, it is advisable to stir the layer of seed at least once a day during vernalization. If all the conditions have been fulfilled, vernalization will be completed in about 10 to 12 days, and the seed may be sown.

OTHER PLANTS

Kononov 65, and Saratov Institute 83.**Lentils.**

A trial was conducted to ascertain the conditions required for vernalizing two early varieties with a vegetative period of 30 days (Indian 168A and Arabian 1221) and seven late varieties with a vegetative period of 43 to 46 days (Saratov Nos. 22, 25, 85 and 298, Krasnokut hoz., Italian 355 and Kursk 210).

The plants were treated at temperatures of 0°, 5°, 10°, 15°, 20°, and 25°C., at humidities of 60, 70 and 80 per cent for 10, 15 and 20 days. It was found that the different varieties responded in a different manner to the treatment; on the whole the vegetative period of the late varieties was reduced in proportion to their lateness, whereas early varieties shewed no response. The greatest effect (a reduction of 5 to 8 days in the vegetative period) was obtained in late varieties at a temperature of 8 to 10°C. and a humidity of 60 to 70 per cent, applied for 10 to 12 days. An acceleration of 3 to 5 days was obtained in mid-early varieties when vernalized at a temperature of 12 to 13°C at a humidity of 70 to 80 per cent for 8 to 10 days.

Saratov Institute 84.**Lentils.**

Experiments were made by I. N. Kononov under the supervision of I. M. Vasiljev at the Grain Husbandry Institute, Saratov, with six late local varieties of lentils which usually suffer from summer drought.

Table 23.

Name of Variety.	Length of the vegetative period, in days.		Reduction in the length of the vegetative period due to vernalization, in days.	Grain yield per plot in kg.		Increase in grain yield due to vernalization, in percentage.	Absolute weight of 1,000 grains in gr.	
	Vernalized.	Control.		Vernalized.	Control.		Vernalized.	Control.
Variety No. 22 ..	76	83	7	211.6	181.8	17.6	62.3	59.1
Variety No. 23 ..	77	83	6	225.2	189.2	18.9	58.1	56.6
Commercial Variety VIZH. ..	76	82	6	191.3	159.1	20.8	42.8	40.7
Petrovskaja 4/105 ..	81	87	6	202.6	179.4	12.9	57.7	53.8
Petrovskaja 4/127 ..	82	86	4	184.5	159.5	16.1	58.5	56.1
Petrovskaja 6/01 ..	78	85	7	186.5	158.7	17.4	73.9	72.2

On the basis of the results of a preliminary test (see preceding abstract) vernalization was made as follows: two weeks before sowing the seeds were brought by three stages to 90 per cent moisture and sprouted at 15°C. until the embryos of 5 - 10 per cent of the seeds had pierced the seed-coat; they were then subjected for 12 days to a temperature of 8 to 10°C. After vernalization the seeds were slightly dried, and sown in plots 100 sq. m. in size on April 20, with 3 to 4 replicates. The control (unvernalized) seeds were subjected two days before being sown to the same pre-vernalization treatment as the vernalized seeds.

Records made at 10-day intervals shewed that vernalized plants developed and accumulated dry matter more rapidly than the control before the onset of flowering. Later, however, the relation was reversed, the control plants growing more rapidly than the vernalized. Nevertheless, the yield and the absolute grain weight was greater from the vernalized plants than from the control; this can be explained by the fact that an earlier termination of the vegetative period in vernalized plants enables them to escape the adverse effects of summer drought. The following table summarizes some results of this experiment.

Česnokov 52.

Beetroot.

Vernalization of biennial plants, the seed production of which presents serious difficulties, is of particular interest. The application of this new method can now justly be regarded as solved in principle, and for its wider use in practice it only remains to elaborate the required complex of factors and the duration of treatment.

Successful preliminary experiments made by Sukorceva in 1930 on the vernalization of beetroot, turnip, cabbage and chicory, which after pre-sowing treatment flowered and produced seed in the first year, enabled the author to lay down in 1932 a more thorough experiment with two beetroot varieties, "Egyptian" and "Bordeaux" in the Physiological Laboratory of the Peterhof Biological Institute.

The seeds were sprouted and from March 14 to the day of sowing were kept at a temperature of 3 to 5°C.

The first sowing of chilled seeds was made on the 43rd day of chilling (Apr. 26), simultaneously with control unchilled seeds. Two months after sowing the chilled seedlings began bolting and on July 16, 12 plants (or 19 per cent) of the Egyptian variety and 4 plants (or 6 per cent) of the Bordeaux variety had bolted. All the remaining plants grew well and formed good roots. Plants from the control seeds, with the exception of a single specimen of the Egyptian variety, did not bolt.

The second sowing of chilled seeds was made on the 68th day of chilling (May 22). In spite of the prolonged exposure of sprouting seeds to low temperature, they were not damaged and produced simultaneous seedlings. On July 16, 13 out of 22 plants of the Egyptian variety had bolted, while signs of bolting were apparent as early as June 17. Similar results were obtained with the Bordeaux variety. Control seeds sown simultaneously produced no bolters. All the plants developed normally.

Summarizing the results of these two experiments the author considers that in *Beta* the duration of vernalization is of particular significance, namely, that the prolongation of chilling increases the percentage of bolters and the rate of bolting. There was no significant difference in the behaviour of the two varieties after vernalization. Bolters of both varieties from chilled seeds differed markedly from the others in habit, e.g., their stems branched vigorously. On Sept. 15 the majority of bolters produced completely ripened seeds, in spite of late sowing and the unusually cool summer.

According to Sukorceva's experiments, which require revision, vernalized but non-bolting plants produced satisfactory roots.

Ivanov 62.

Flax.

The object of an experiment in 1930 was to demonstrate the capacity of flax

seedlings to resist spring frosts of up to -5°C and secondly to ascertain the influence of such chilling upon subsequent development and yield. It is sufficient here to note that low temperatures are not a limiting factor to the extra-early sowing of flax in view of its winterhardiness and marked capacity for hardening.

In order to test this influence of chilling upon subsequent development and yield, plants from the previous experiment which had been chilled at different developmental stages at temperatures of -3° to -5°C were grown under normal conditions until maturity. The action of low temperatures resulted in:

(1) Marked delay (4 to 13 days) in flowering, increasing according to the earliness at which the plants had been subjected to the low temperatures, and to the lowness of the temperatures.

(2) A reduction in height of plant until flowering, while after flowering the chilled plants rapidly surpassed the control plants in height; this was more marked when the lower temperatures coincided with the earlier stages of development.

(3) An increase in the total dry matter and the acquisition of several valuable characters such as increase in the stem length, improvement in technical value (fibre) and larger number of fruits per plant.

A comparative anatomical study of the stem shewed that the areas of the phloem and xylem are increased equally at the expense of the medullary area, that there are changes in the relative proportions of different tissues of the stem and that there is an increase in the area of the fibres at the expense of some other elements of the phloem.

The above results led the author to conclude that the chilling of flax seedlings at a temperature which produces no visible harmful effects nevertheless produces a series of changes in the function of the meristem resulting in the morphological and anatomical differences between chilled and non-chilled plants described above.

Kostov 68.

Miscellaneous crops.

Seeds of maize, millet, soya bean, sorghum and Sudan grass are moistened prior to vernalization in the same way as cotton seeds, but the temperature should be about 10 to 15°C . The moisture should be sufficient to make the seeds germinate, but the plumules should not be allowed to grow longer than 2 to 3 mm. for maize and 1 to 2 mm. for the other crops. The amount of water per 100 parts of seed is 26 parts for millet, sorghum and Sudan grass, 30 parts for maize and 74 parts for soya bean.

When all the water has been completely and uniformly absorbed, the sprouting seeds are transferred to the conditions required for vernalization, as follows:

maize at 20 to 30°C . for 10 to 15 days,

millet at 25 to 30°C . for 5 days,

soya bean at 20 to 25°C . for 10 to 15 days,

sorghum and Sudan grass at 25 to 30°C . for 8 to 10 days.

It should be remembered that all these plants require a certain period of darkness before they can flower. The required darkness can be supplied by protecting the seeds from light during vernalization.

Mould attacks during vernalization are prevented by thorough stirring at least once daily. If the seeds of soya bean are attacked by mould, they should be sown immediately, even though their vernalization has not been completed. If the seeds of the other crops shew traces of mould, they should be spread in thinner layers and the temperature within the layers reduced to 15°C .

Ivanov 63.

Miscellaneous plants.

The author has been able on the basis of Lysenko's principles to postulate the

possibility of influencing the processes responsible for an intensive rate of accumulation of organic matter during the subsequent growing period by subjecting young seedlings to definite external conditions. Experiments were made at the Institute of Plant Industry, Leningrad, in 1932 on the response of various varieties of plants to the influence of low temperature. The following plants were included:

Ervum Lens.

Cicer arietinum (late var. No. 16 and early var. No. 5).

Coriandrum sativum (late var. K-75 and early var. K-55).

Eruca sativa (K-25).

Camelina sativa (K-1532).

Helianthus annuus.

Carthamus tinctorius (K-49).

Papaver somniferum (early var. No. 38073 from Turkey,
early var. No. 62677 from Asia Minor, No. 124.
Late vars, No. 113322 and 113318 from West China.)

Linum usitatissimum (early var. K-930 and Sredne-Buharskii No. 341.)

Seeds of these plants were grown in pots. After appearance of the seedlings, they were chilled at 3 to 5°C. for 11 and 30 days. Immediately after chilling the experimental plants did not differ much from the control, though their growth was somewhat retarded. Later, however, the influence of chilling on the vigour of growth became marked, but the effect varied in different plants. Chilled plants of *Helianthus annuus*, *Carthamus tinctorius*, *Camelina sativa*, *Coriandrum sativum* and *Eruca sativa* grew better than their respective controls, i.e. their leaves became larger and they soon overtook the control in height. The average fruit yield of these plants was also markedly increased. Chilling had a less stimulative effect on *Coriandrum sativum* K-75, *Camelina sativa* and *Eruca sativa* and the total yield of their chilled plants was 6.6, 19.7 and 17.6 per cent higher than their respective controls. In *Ervum Lens* and *Cicer arietinum*, on the other hand, the vigour of growth fell considerably soon after chilling, with the result that the average weight of stems and leaves, height of plants and average fruit weight were decreased. Total yield was 10.3 per cent lower in chilled plants of *Cicer arietinum* No. 5; 26.3 per cent in *C. arietinum* No. 16, and 61.8 per cent in *Ervum Lens*.

Chilling also retarded flowering in all cases; in the vigorous plants for a period not exceeding the duration of chilling, and in the slow growing plants (*Cicer arietinum* No. 16, by 15 days and *Ervum Lens* by 25 days) for a period longer than chilling, (with the exception of *C. arietinum* No. 5, retarded for 7 days), i.e. in the plants of the second group a negative correlation between total yield and length of vegetative period was evident. No correlation between the vigour of growth and the rate of development could, however, be traced in the plants of the first group; thus, for instance late and early *Coriandrum sativum* delayed flowering for 11 days while their total yield was respectively 106.6 and 214.0 per cent as compared with their controls.

The comparative effect of chilling for 11 or 30 days was investigated on two *Linum usitatissimum* varieties and on five varieties of *Papaver somniferum*. In the case of early flax, low temperature reduced total yield and the effect was stronger with the prolongation of chilling. The total yield of Sredne-Buharskii flax was increased after 11 days' chilling by 14.1 per cent and after 30 days' chilling by 44.0 per cent. All *Papaver* varieties responded similarly and their total yield was greater with increasing duration of chilling. It should be noted that in these *Papaver* varieties and Sredne-Buharskii flax increase in the total yield caused by chilling is due largely to the increase in seed yield, whereas the decrease in the total yield of early flax is less connected with the decrease in seed yield. The effect of chilling on *Papaver*

varieties was expressed also in larger leaves, longer stems and better developed pods.

As in the previous experiment chilling retarded flowering and the delay was greater with a prolongation of chilling, although in all cases it was retarded for a time shorter than the respective duration of chilling.

Therefore low temperature has a definite effect on the progress of growth processes in seedlings and the changes induced therein manifest themselves in the rate of growth during the subsequent growing period. When chilling favours the normal progress of growth, the vigour of accumulation of organic matter (and consequently the yield) is increased, whereas when low temperature is not optimum for the progress of growth, whether from the quantitative or qualitative aspect, or when it does not correspond to the developmental stage of a plant, a fall in the vigour of growth occurs and the yield is consequently reduced.

The absence of any consistent correlation between the change in the total yield induced by chilling and the delay in flowering which, as a rule, does not exceed the duration of chilling, confirms Lysenko's statement that growth and development are not correlated and can, to a great extent, progress independently. Though the mechanism of the effect of low temperatures responsible for changes in growth processes is probably connected with assimilation, yet it is not impossible that low temperature may also have an effect at still earlier stages, e.g. on sprouting seed. The results obtained indicate also that the yield of those plants which respond favourably to low temperature may be increased by an ultra-early sowing.

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5.—APPLICATION OF THE THEORY OF PHASIC DEVELOPMENT.

A.—BREEDING.

Lysenko 106 and 107.

Physiological bases of breeding.

In the first presentation of the principle of vernalization to the Genetics Congress at Leningrad in 1929, vernalization was said to be only one of the various stages known. From the understanding of this stage and the theoretical assumption of the existence of succeeding stages, it was made possible to convert any winter crop into a spring form and many late spring forms into earlier ones through an understanding of the retardation in earing when these are sown in spring. The basis of the Theory of Vernalization is that plant development consists of stages, only two of which, the "vernalization" or thermo-stage and the photo-stage, are yet known*; the establishment of these two, however, justifies the assumption of a series of stages in plant development and the application of the principle of phasic development to the work of breeding and genetics. The theory has become known in many circles merely as an isolated agronomic method, which is unfortunate, for vernalization, constituting as it does only one out of many phases of development, in reality forms the basis for the explanation of the whole course of development of the plant. From this point of view scientists have still largely failed to appreciate the principle of vernalization and thus the theory of plant development as a series of stages in the life of the plant. Successful breeding can only be carried out with a knowledge of the true hereditary nature of the parental forms, for which in turn a true understanding of the plant itself from the above point of view is necessary. Lysenko is opposed to any genetics where this knowledge is absent or is not taken into account.

The embryo of a seed and a growing plant may react to many different environmental influences. Only certain of these reactions lead to the completion of the cycle of development from the seed sown to the seed ripened in the ear and only this reaction is regarded by Lysenko as "development."

The development of a plant organism consists of several stages, through each of which the plant passes as a result of the reaction to the external conditions. Different stages of development of one and the same plant require different external conditions. This does not mean that for a given stage the plant demands absolutely definite conditions, since it is well known that these conditions may vary within certain limits. From this it follows that the development itself, which is the reaction of the organism with the external conditions, may vary too, and so the same genotype may develop relatively different qualities and characters.

Thus, as affected by the after-sowing conditions, the same variety when sown in spring may behave as a winter form in one region and as a spring form in another. Again, the lateral ears of awned wheats, which have developed later and thus under conditions different from those prevailing in the main ear, are often without awns; and as a result of vernalization some other properties of the plants may be changed, thus after vernalization some immune varieties sometimes become susceptible and susceptible varieties resistant or immune. In experiments made in Detskoe Selo, Odessa and Hibiny with various cereals, as a result of vernalization, i.e. intervention in one single developmental stage, the thermo-stage, many varieties which otherwise display no features of particular value, or even do not come into ear,

*A third stage has been discovered since the appearance of this article under review (see p. 16).

have after treatment proved considerably better than the varieties commonly grown in these districts. The genetic constitution of these varieties remained unchanged, but their behaviour altered, for having passed through the first stage before sowing, these plants completed each of the succeeding changes a little earlier than unvernallized plants growing in the same field. Hence the conditions under which each stage was passed through were different and this led to agronomically quite different results. By such a shift in the time of completion of the developmental stages, not only the time of earing, but also through it the quality and character of the grain were affected. Hence in sowings made at Odessa in 1933, one lot of which had received optimum conditions for the thermo-stage, the second lot for the photo-stage, the third lot for both these stages, and the fourth lot being untreated, the degree of vitreousness was different in each lot. Again, in the majority of wheat varieties tested at Odessa in 1933, the increased earliness after vernalization was associated with better grains, viz., the 1,000 grain weight was as high as 60-70 gm., while the untreated were all inferior to the local varieties. The standard local varieties when grown under conditions optimum for the photo-stage also improved the quality of grain. Thus Girka 0274, when its development was accelerated by 6-8 days, increased the absolute weight of grain from 17.8 to 28 gm. The table given below illustrates also a correlation between the time of earing and the absolute weight observed in a further experiment made with 879 wheat varieties.

Table 24.

Acceleration in earing in days.	No. of varieties acceler- ated in earring.	No. of varieties not increasing the 1,000 corn weight.	Number of varieties increasing the 1,000 corn weight.				
			From 1 to 5	From 6 to 10.	From 11 to 15.	From 16 to 20.	From 21 to 25.
1	—	—	—	—	—	—	—
2	2	—	1	1	—	—	—
3	13	2	3	4	1	2	1
4	22	2	6	4	7	2	1
5	58	3	10	30	9	4	2
6	98	12	18	36	23	16	3
7	122	8	14	30	31	27	12
8	157	7	15	38	44	39	14
9	150	1	10	33	37	40	29
10	95	1	4	16	21	29	24
11	53	1	4	6	12	20	10
12	39	1	—	8	6	14	10
13	22	—	—	2	2	6	12
14	22	—	—	—	2	10	10
15	26	—	1	—	4	7	14
Total ..	879	38	86	198	199	216	142

These various examples are enough to shew that any given organ or character is the result of the development of the plant, which itself is the result of the inter-relationship between the organism and the environmental conditions. Thus under different conditions of the medium and hence of development, different organs, characters and qualities will be produced. With this point of view the majority of

geneticists are in agreement, but with certain reservations, namely that there must exist some genetically "stable" characters, which are invariable and constant and depend only on the hereditary constitution of the individual and are independent of conditions. Such a view must be the result of a confusion of two distinct things, the medium itself and those conditions of the medium made use of by the developing plant. It is quite possible to alter the medium without changing those particular conditions that take part in the development of the plant as a whole and of the particular organ or character under observation, leading to the erroneous conclusion that the medium does not affect the given character. Conversely it is possible that without altering the medium, the conditions influencing the development of the plant or one of its organs may vary considerably and so effect a very different type of development. Lysenko gives a photograph which shews the difference in development between plants of the same variety of barley sown in the same medium (the field), but on different days, March 12 and March 14. The March 12 sowing came into ear and the March 14 sowing remained in the rosette stage. The real difference between these two lots sown in apparently identical media is that for two days one lot was at a temperature of 2-3° lower than the other.

The view that the development of the characters does not depend on the hereditary constitution of the embryo from which the plant in question develops is equally erroneous. The development of the plant, and so its individual organs, characters and properties is influenced by the reaction between its inherent qualities and definite external conditions. As a result of differences in development, differences in the various organs and characters and different quantitative expressions of these arise. Each stage of development is the starting point for particular organs and characters, which may in turn be the starting points for other organs and characters.

The problem of the breeder is by suitable crossing to produce a genotype such that its individual development will give a form suitable for the conditions of the region for which it is designed. It quite often happens, however, that a variety produced in one region is just as suited, or even more so, to another region, as in the case of *Kooperator*, produced at Odessa, and hardly grown at all in the Odessa region, but grown very widely in the Caucasus. The breeder must have a very intimate knowledge of the conditions and requirements of his region, so as to combine the genotypes in such a way that the development of the resulting plant and of its individual organs, characters and properties will take place in the field at the most favourable moments and so give the optimum results. Geneticists and breeders in the past have not chosen their parents on these lines, they have made the mistake of choosing them according to their phenotypical characters rather than according to their hereditary nature. For instance, just as the same genotype developing in different circumstances may give different results, so also different genotypes in different conditions may give the same type of plant and therefore appear alike. A knowledge of the interrelation of internal nature and external conditions, however, makes it possible to appreciate the true genotypical constitution of a plant and even to recognize the genotypical nature of new segregates without resorting to hybridization with them. The investigations of the Ukrainian Breeding Institute have been directed to the study of the conditions required by different genotypes to produce seed. It has become evident that the development of the plant as a whole is not continuous, but takes place in stages. When the external conditions required for a particular stage, e.g. the thermo-stage, are known, it is not difficult to say in what conditions or regions any variety will behave as a spring form and in which as a winter. It is now known that genotypes, e.g. different wheat varieties, differ considerably in their degree of winteriness, although winteriness itself is not one of the characters constituting the genotype. It is therefore known what will be

the behaviour of any variety in a particular locality. This knowledge itself has advanced one step further the comprehension of the hereditary nature of spring and winteriness. The hereditary basis does not consist in whether the plant develops as a spring or winter form. It is now also known that in addition to the thermo-stage there exists another stage, the "photo-stage," which can proceed only after the thermo-stage, the qualitative changes in the cells occurring during the thermo-stage being necessary for its inception. That these changes are of a specific qualitative kind can be easily shewn by the staining reactions of the tissue. (cf. Bassarskaja p. 47, Richter p. 49). The remaining stages are not yet known, but there are apparently not many of them, probably five. It is essential that further study be devoted to discovering and elucidating these stages too. Each stage of development is characterized by different characters and properties and the appearance of different organs, for the development of which different external conditions are required. Hence to study any particular organ it is necessary to know at what stage of development the said organ or character appears. This will indicate the internal, hereditary factors on which the organ or character depends. If each organ, character and property is studied from this point of view it should then be possible to predict what kind of property, character or quality any given genotype will produce. For this every organ and character must be studied separately, studying their opposing possibilities and the stages at which each develops.

In practice it is well known more or less under what conditions any variety of any cotton or wheat will give a crop, but what the precise nature of this crop will be, whether the plants will be large or small, etc., etc., is beyond prediction. This is because only the development of the plant as a whole and not the development of its individual parts has been studied. However, the study of the plant as a whole has progressed to a certain extent, so that it can now be said which varieties will behave as winter varieties and which as spring in which particular regions, where certain wheat varieties will be early and where late; but this can still be said only approximately, as only two of the stages of development have been investigated and hence the length of the vegetative period is still not precisely known. Investigations must be made on the hereditary nature not only of the individual stages of development of the plant as a whole, but of its individual characters and properties.

On the basis of the present knowledge of the first two stages of development of the plant as a whole in such plants as wheat, oats, barley, maize, soya bean, cotton, hemp, etc., it is possible to choose suitable parental pairs, such that their progeny will possess the precise vegetative period required by the breeder. Several pairs of late wheats, oats and barleys at Odessa can be indicated which on crossing will unfailingly produce ultra-early forms, and other pairs of medium-early varieties which on crossing will give late segregates. This has been made possible only by the study of the general development of the plant. By the use of the world collection of wheats on these lines, it ought to be possible to create forms of any desired vegetative period in any particular region.

The production of early forms by crossing two late varieties is achieved as follows: one variety may be late in a given region because it takes too long to pass through the thermo-stage, all other stages being capable of passing quite rapidly in the district in question, including the "photo-stage"—such a variety will be late only because of the delay in the thermo-stage. Another variety is delayed in the "photo-stage," all other stages of its development, including the thermo-stage, passing rapidly—this variety will nevertheless also be late. Varieties of these two types were crossed in 1933 and the F_4 generation is now growing. Segregates have already been obtained that are earlier than both parents in nearly all the thirty combinations of this type that were made. There were a few exceptions, probably owing to the existence of other stages influencing the vegetative period besides these two.

It is important to emphasize that the forms obtained will have the desired vegetative period only in the regions for which the parents were chosen. The vegetative period of any variety may be entirely different in one neighbourhood from another, for instance the Indian wheats in Azerbaijan are considerably earlier than the Finnish wheats, but at Hibiny they are definitely later.

The success of the above method of producing early forms where the pure genetical method has failed is the result of the approach through the interaction of the internal properties of the plant with a definite complex of external conditions, whereas formal genetics concerns itself entirely with the end products, the characters. Formal genetics is in fact concerned not with genotypes, but with phenotypes.

By the above method it ought also to be possible to produce varieties of such plants as runner beans, soya beans and maize capable of ripening in northern latitudes. For this purpose they should be sown under field conditions, and 7-10 days after germination exposed to reduced length of day for 20-25 days and the best variety chosen as one of the parents, this being the variety in which the length of day is the only limiting factor. The other parental variety must be chosen amongst the control plants grown in the open, being the variety which best reacts to the long northern day. Similarly with cotton, there are many varieties that are late for a number of different reasons and by crossing them it should be possible to produce types earlier than the parents and even than the varieties commonly grown in the district in question.

The choice of parents is made by growing the prospective parents artificially under the conditions of cultivation—length of vegetative period, etc., etc.—for which the new variety is designed and those which react most satisfactorily as regards quantity and quality of the yield are chosen as the parental varieties.

Sapehin 111.

Accelerating breeding.

In cases where to an otherwise suitable variety one particular character in which it is deficient has to be added, the late L. A. Sapehin recommended the method of repeated back-crossing over a number of generations. It is calculated that if the variety to be improved differs from the other one in one gene, 99 per cent of the back-cross progeny will be like it in the sixth generation whereas with increasing numbers of gene differences this number falls sharply, so that with seventy gene differences only 30 per cent will be of the desired type in the F₈. Such a method is only possible if three to four generations can be grown in one year, and in this connexion the method of vernalization is of particular importance. The experiments of the Ukrainian Breeding Institute have shewn that it is quite possible to grow three generations of winter wheat and four generations of spring wheat in the greenhouse, but for this it is essential that the correct temperatures for the stage of vernalization are provided, and this must be followed by a period of about three weeks of continuous illumination or at least long day.

Paljmova and Basova 108.

Breeding for earliness.

The world collection of wheats shews very clearly that early maturing wheats are to be found in four main regions, the arctic, the continental regions of the sub-tropics, mountain regions and the countries of periodic rains such as China and Japan.

In other respects the wheats of these four groups are very different in type. The northern forms have a low heat requirement and a pronounced reaction to light, the southern forms are tolerant of high temperatures and do not react to light. These groups, moreover, behave differently in inheritance, the earliness of the southern early forms (from India, Australia, Syria etc.) is dominant and transmitted to nearly the whole of the progeny, whereas the earliness of the steppe wheats is

sometimes dominant and sometimes recessive. These differences are dictated by the variation in light requirements of the different types. The southern forms do not react to light because they have a low light requirement; yet their sensitivity to light is said to be as pronounced as that of the northern forms. By crossing these two extreme types, forms with varying light requirements will arise, and so forms varying in earliness.

Kostjučenko 104.

Wheat breeding.

In making use of the world varietal collection for building up new strains success entirely depends upon the appropriate choice of parental forms. Nilsson-Ehle has shewn that to assess the value of varieties they must be grown under conditions in which they are able to complete their vegetative cycle normally. The mild conditions of southern Sweden enabled Nilsson-Ehle to test winter and spring varieties in the open, but under the more severe conditions of U.S.S.R. such a test can be applied only in conjunction with vernalization.

Lysenko and Sokoljskiï recommended the adoption of the following schemes for choosing the best parental plants for hybridization. Wheat or barley varieties should be sown both in the vernalized and unvernallized state. The best local strains should then be crossed with those which after vernalization proved to be the earliest and of the best quality. The seeds of the most suitable hybrid plants should be sown immediately in greenhouses in order to obtain seed in the next spring.

Soya beans or beans should be sown in two replications; one replication should be grown throughout under normal seasonal conditions and the second should, on the 10th day after the appearance of the seedlings, be transferred to a short 10-hour day for 25 days. The earliest strains which, however, do not respond to the shortening of the day should be crossed with those which were earliest and most productive under short-day conditions.

Although the schemes suggested have great merit they do not entirely solve the problem of testing strains for crossing, for apart from the great significance of the pre-sowing completion of the first stage (vernalization) there is a second stage, the optimum completion of which would not only permit the transference of plants to new, perhaps more favourable, conditions for their further development, but also shorten the length of the vegetative period. The changes in the vegetative period might cause further changes in some other characters of agricultural value.

The significance of light as well as of temperature is very extensive and Table 25 illustrates clearly the influence of length of day on the vegetative period and thousand grain weight. The temperature vernalization of the strains tested in Detskoe Selo (near Leningrad) and Hibinogorsk (67°N. Lat., 30°E. Long.) produced little difference in the vegetative period but the long day reduced it by 5 to 9 days. This was accompanied by an increase of 0.6 to 6.6 grm. in the thousand grain weight, which can thus be attributed to the optimum progress of the photo-stage under the conditions of the continuous day in Hibinogorsk. Therefore, while studying the initial strains it is absolutely necessary to provide the plants with such photoperiodic conditions as will ensure the optimum progress of the second stage, i.e. long-day plants should be tested under a continuous day and short-day plants under a shortened day.

In choosing parental plants the purity of the strains tested is also of great importance. For example in experiments carried out at the Institute of Plant Industry, Leningrad, it was found that even individual plants of the same strain shewed different responses to vernalization (first stage). This is particularly noticeable in local winter varieties. Various winter varieties of wheat were vernalized at a temperature of 2°C. for 20, 25, 35 and 45 days and then sown simultaneously with the controls. Only 12 of the 60 varieties tested shewed a clear response to the pre-sowing treatment; some of these, however, eared simultaneously only when

Table 25.

Origin and name of variety.	Number of days from seed- ing emergency to earing.				Minimum reduction in vegetative period due to increased length of day.	Thousand grain weight.				Increase in thousand gram weight as a result of increased length of day in the second developmental stage.
	Detskoe Selo.		Hibinogorsk.			Detskoe Selo (18 hour day).		Hibino- gorsk. 24 hour day).		
	Vernalized.	Control.	Vernalized.	Control.		Vernalized.	Control.	Vernalized.	Control.	
U.S.S.R. " Novinka' <i>Erythrospermum</i> ..	42	42	33	34	8	18.3	18.9	39.1	36.8	2.9
India, Pusa 52 <i>Graecum</i>	42	42	33	33	9	18.4	18.1	40.3	39.2	0.6
Asia Minor (21105) <i>Reichenbachii</i> ..	42	43	35	35	7	16.3	15.3	37.4	32.6	3.8
South Africa (25626) <i>albidum</i> ..	39	38	33	33	5	22.0	20.5	47.7	39.6	6.6
Canada, " Garnet " <i>lutescens</i> ..	39	39	33	33	6	17.6	17.3	27.7	32.6	4.8
Australia (25550) <i>alborubrum</i> ..	42	40	34	34	6	17.2	20.7	36.5	34.5	5.5
U.S.S.R., Moskov- skaja 2411 <i>erythrospermum</i> ..	47	winter	41	winter	6	19.2	—	—	—	—
U.S.A. " Nebraska " <i>erythrospermum</i> ..	48	„	41	„	7	20.4	—	—	—	—

Note.—Seeds sown in Detskoe Selo and Hibinogorsk are of the same origin and similarly vernalized.

vernalized for a definite number of days, retaining their winter character after other durations of treatment. Moreover in the strains which eared simultaneously after being vernalized for 35-45 days or 25-45 days there were plants which retained their winter or semi-winter character.

Again in spring sowings made at Detskoe, it was observed that some plants of Chinese and Japanese wheats eared normally while others behaved as winter or semi-winter forms, whereas when vernalized the same varieties eared and matured in a normal and practically uniform manner.

Therefore several winter strains revealed a difference in respect of their first and second developmental stages and many lines which are morphologically pure are definitely heterozygous with regard to their developmental stages. This heterozygosity is regarded as being partly responsible for the irregular segregations

frequently observed in some characters such as yield, earliness, etc. Therefore in choosing a variety, line or sample for breeding it is not enough to know the response to vernalization or photoperiods, but it is also necessary to find those conditions which are required for the optimum completion of the first and second stages of the individual development of plants i.e. to deal not with the collection of individual plants of this or that strain, but with the progeny of the same selfed plant from a definite strain, variety or sample.

Krasnjuk 105.

Effect on seed ripening.

The author investigated the possibility of accelerating breeding by shortening the time required for seeds to reach complete maturity (including the after-harvest ripening), by testing the germinability of seeds at various stages of ripening, using five cereals (three spring and two winter varieties); the latter were both vernalized and unvernallized.

From the 6th day after 50 per cent flowering, ten ears were gathered every second day until the grains were fully matured. In each sampling grains were picked from five ears; one lot of these grains was tested on the day of picking and the second was dried at room temperature for five days before testing.

The non-dried grains germinated better than dried grains, the latter being slightly superior only in late varieties. Germination in early samplings was low and the rate of its further increase varied markedly between the varieties tested. The maximum germination was shewn by grains at the wax-ripe stage. Grains from vernalized winter plants generally began to germinate earlier than those from unvernallized plants. For example, as early as the 16th day Eliseevskaja rye and the winter wheat *Lutescens* 329 acquired 93 and 96 per cent germination respectively, the progress of maturation having been greatly accelerated by the pre-sowing treatment. Therefore, since winter varieties are generally harvested on the 38th day after flowering, the obtaining of grains with a normal germination on the 16th day will mean a gain of 22 days; if the 10 days for after-harvest drying are added, the total gain is one month. This alone makes it possible to obtain two generations a year in the greenhouses.

A comparison between the germination of non-dried grains in Petri dishes and of dry seeds in ordinary field sowings shewed that the grains from early collections can shew a high germination at very early stages of their development. It is also quite possible that pre-sowing treatment will accelerate the maturation required for normal germination in spring forms.

The thousand grain weight is also rapidly increased and by sowing the grains of certain early collections, a quite normal seed yield is obtained. Only in development were the plants from very early collections somewhat inferior.

B.—FAR NORTH.

Eichfeld 100.

Far North.

The Polar Division of the Institute of Plant Industry at Hibiny is the most northerly research station in existence and is in many other ways unique. The continuous polar day gives an unparalleled opportunity for carrying out experiments on photoperiodism and the like and one of the first results of importance is the discovery that the 24 hours of uninterrupted sunlight at the low temperatures there prevailing has a very different effect on plants from that of continuous artificial illumination in the greenhouse. Potatoes for instance when grown in 24 hours sunlight at Hibiny gave, contrary to current opinion and expectation, quite high yields of tubers, in many cases higher than those obtained at Leningrad and regularly higher than those from further south, Odessa and the North Caucasus. Experiments designed to look into this phenomenon have shewn that the low temperature is the

distinguishing factor: at temperatures of 12-15°C. the vast majority of potatoes proved to be long-day plants, whereas with rising temperature their yield diminished and no tubers at all were formed at 25-30°C.

Many root crops from southern countries bolted in the continuous northern day, e.g. beets from Afghanistan bolted without exception and those from western Europe gave a small proportion of bolters. For this reason the Sugar Research Institute is testing all its sugar beet selections for bolting at Hibiny. Similarly all forms of black radish bolted, whilst the more northern, recessive white forms did not. Spinach and many salad plants can only be cultivated by curtailing the length of day and turnip becomes a silage plant, developing a mass of green matter and very little root.

Just as in the case of potatoes, the long day combined with the low temperature make it possible to grow varieties of barley, and also of wheat and oats, that will not grow in Leningrad, e.g. good yields have been obtained from a barley from Asia Minor which at Leningrad fails to come into ear. It has been shewn that both these factors must be operative together, for a reduction of the day length while retaining the same low temperature has a no less unfavourable effect on tuber production in potatoes than the raising of the temperature under continuous illumination.

The method of vernalization, "discovered and brilliantly worked out by T. D. Lysenko" is beyond all doubt of immense importance in connexion with the extension of the northern limit of cultivation of grain crops. With the object of testing this, sowings were made, under Lysenko's direction, of 900 wheat varieties in 1932 and 3,500 in 1933, representing wheats of 47 countries, including those of the extreme south. In 1933, 500 varieties of oats and 1,600 of barley were also sown by the section of physiology and 260 wheats and 300 barleys by the genetics and breeding section of the Institute of Plant Industry.

As a result of vernalization many southern varieties of wheat succeeded in ripening and also even winter and semi-winter varieties of barley which without vernalization in Hibiny do not even come into ear.

It is interesting to note that some of the wheat varieties behaved differently at Hibiny from Odessa. Applied to the whole collection of wheats, vernalization accelerated ear development by 2-4 days in the majority of varieties, by 5-10 days in 12 per cent of the varieties and by more in 17 per cent. In 8.5 per cent of the varieties no change was produced and in 1.5 per cent a retardation.

The conjunction of breeding and vernalization, the author asserts, offers great possibilities for these northern regions; it should be possible by its means to create new varieties suitable for northern cultivation and at the same time greatly to increase the range of varieties that it is possible to employ as parental forms.

Razumov and Smirnova 110.

Far North.

The continuous natural sunlight of the arctic circle is peculiarly favourable to experiments involving the second of Lysenko's developmental stages, the "photo-stage." The world collection of barleys was vernalized in the ordinary way; the seed was brought to a moisture content of 50 per cent and after retaining at room temperature for 24 hours was subjected to low temperature, the winter varieties at +2°C. for 30-35 days, the spring varieties at +6° to +8°C. for 15 days.

In all 1505 varieties were tested. After vernalization, all varieties came into ear and moreover did so more or less uniformly between July 12th and 20th, whereas only 665 of the 1,505 varieties eared in the control sowing and their earing was much more irregular and delayed; never more than 8 per cent of the varieties came into ear on any one day whereas in the vernalized lot sometimes as many as 26 per cent, i.e. 394 varieties, eared together on the same day. Between July 12th and 20th, when 81 per cent of the vernalized varieties eared, only 25 per cent of the controls emerged.

In both cases the number of varieties which ripened was less than the number in which ears emerged, but yet this number was increased by vernalization from 15 per cent to 42 per cent, thereby increasing by three times the number of varieties it is possible to grow in the arctic circle. The behaviour of the barleys from different countries is shewn in Table 26. Forms earing and maturing before the standard, Pioneer, were obtained from Italy, Spain, Asia Minor and India and those from northern countries like Sweden and Finland reacted very markedly to vernalization.

Table 26.—Behaviour of varieties of barley from different countries.

Countries.	Number of forms.	Percentage which eared.		Percentage which ripened.	
		Vernalized.	Control.	Vernalized.	Control.
Sweden, Finland	25	100	48	52	8
Spain, Italy	113	100	95	86	17
North Caucasus	472	100	33	42	17
Azerbaijan	229	100	11	29	5
Asia Minor	56	100	89	35	7
India	*	100	22	44	2

*Number not stated.

The varieties distinguished by the best agronomic qualities after vernalization were those from the North Caucasus, which though not quite so early as the Italian and Asia Minor forms, yet ripened and gave a yield as high as the standard spring barleys. These results will undoubtedly disclose certain varieties not hitherto considered, which after treatment can be grown with advantage on a large scale, and a number more which will make valuable parents in breeding; experiments in progress shew that there is every reason to believe that the same applies to wheat, rye, oats, and a number of other crops. All the previous ideas on the relative merits of the varieties will have to be changed in the light of the behaviour after vernalization. Moreover by the application of the method of choosing complementary parental pairs proposed by Lysenko it will be possible to build up successful new varieties that do not require vernalization.

Cereals are sown immediately after the snow goes from the ground and it is not at all infrequent that there should be further falls, and night frosts occur regularly up to the end of June. Now most northern plants, such as radish, turnip, beet, etc., require low temperature, from 0° to $+6^{\circ}\text{C.}$, for the first developmental stage, which at the lower temperatures, 0° to $+2^{\circ}\text{C.}$, passes most rapidly and with rising temperature is retarded, until at $+15^{\circ}$ to $+20^{\circ}\text{C.}$ it is practically arrested. Each variety has its own particular requirements of temperature, moisture, etc. Thus southern varieties of the above plants achieve the first stage at relatively high temperatures, and in the arctic regions tend rapidly to go to seed, whilst northern forms require very low temperature for a protracted period, up to 90 days, and so fail to fulfil their cycle in the short arctic summer. In view of this, and by using the method evolved in Lysenko's laboratory for determining the rapidity of achievement of the first stage by the colour reaction of the growing point (see section 3), it will be possible in the laboratory to rule out all those varieties which are palpably unsuitable and select the ones which by the nature of their first stage are most likely to be adapted to northern conditions. Thus the knowledge of the principles of vernalization makes it possible to select forms that do not require vernalization. On the other hand vernalization of cereals is definitely a practical proposition, largely

because they require a lower temperature for the first stage than the above vegetables. This is illustrated by the barleys of Italy and Spain. All but 5 per cent of these came into ear unvernallized but only 17 per cent of them ripened grain, as compared with 86 per cent in the vernalized lot. This is explained by the fact that the ears of the vernalized lot all emerged in the course of 5 days whilst the controls were earing over a period of 46 days. Thus although the first stage could be accomplished in the control plants it took place so slowly that the majority of the ears were unable to mature their grain. This effect is ascribed partly to the rise of the temperature during the day. The effect is more pronounced, as already seen, in the other barleys, which without vernalization mostly do not form ears. Thus it appears that notwithstanding the low temperature in the arctic circle in summer and especially in spring, it is yet necessary to apply vernalization because the temperatures are not low enough and the first stage, even if achieved, takes place too slowly to be serviceable.

The second developmental stage is that which requires light, and here again the varieties differ in their precise requirements, mainly in their different degree of sensitivity to length of day. For instance, in Abyssinian barley ears emerge in a 12-hour day after 32 days and in an 18-hour day after 27 days, i.e. an acceleration of 1.2 times, whereas Swedish barleys ear in 82 days in the 12-hour day and in 44 days in the 18-hour day, this being an acceleration of 1.9 times. In general varieties from the south pass through the second stage most rapidly in a 24-hour day, but a slight reduction of this to 18 or even 15 causes very little retardation. Northern varieties, however, are extremely sensitive to length of day in the second stage and even a small reduction in the daily illumination brings about a marked retardation. Thus northern varieties are greatly accelerated when grown in the arctic circle, but southern ones are affected much less.

To test how far these northern conditions are the ideal for the accomplishment of the second stage plants were grown in different lengths of day at high temperatures in the hothouse, where the temperatures varied between 15° to 35°C., and at natural temperatures in the open. The barley used was Pioneer and had been preliminarily vernalized; the results are shewn in Table 27. As the first stage in Pioneer has no special requirements, the early development was the same in both. But in the second stage the development was very different in the 24-hour day treatments at different temperatures; the low temperature retarded the develop-

Table 27.

	Number of days to earing.				Total weight of plant.			
	Hothouse.		Open.		Hothouse.		Open.	
	Total.	Per cent.	Total.	Per cent.	grm. .	Per cent.	grm.	Per cent.
24-hour day ..	29	100	35	120	157	100	458	291
15 " " "	35	120	42	145	125	79	270	171
10 " " "	—	—	—	—	133	84	200	127

ment, and by the same amount as the plants were retarded at high temperature by a 15-hour day. This is because light, though the most important factor for the second stage, is not the only one and cannot be considered without relation to temperature. The work of the physiological laboratory of the Institute of Plant Industry has shewn that in some varieties of barley the second stage is never completed at a temperature of +7° to +8°C. even with optimum light conditions. Thus under certain temperature conditions continuous light may have exactly the same effect as darkness.

It seems evident, therefore, that under the low temperature conditions of Hibiny at night, the second stage may be entirely arrested or very materially retarded. The intensity of the natural illumination is always considerably above that required for the second stage and the reduction in light during the "night time" cannot be regarded as a possible cause of the retardation. Every variety has its own temperature requirements also for the second stage. To illustrate this two more varieties were vernalized and grown in the same conditions of hothouse and open. The varieties were Pioneer and a barley from Asia Minor. The former eared in the hothouse after 23 days and the latter after 24 days, whereas in the open the Asia Minor barley only eared after 42 days, Pioneer after 36. This shews that the same continuous day was less favourable to the Asia Minor barley on account of its different temperature requirements, than to Pioneer. It is therefore extremely important to study the temperature requirements of the different crops in the second stage, both in choosing parent forms and for cultivation.

A barley from Bokhara came into ear on the 47th day when grown in continuous light both in the hothouse and in the open. However, when it was vernalized, it eared after 35 days in the hothouse and only after 47 in the open. It was thus the extreme sensitivity of this barley to both the first and second stages that made it take the same time in both high and low temperatures—in the unvernallized stage the first stage was retarded by the high temperature in the hothouse treatment and the second stage was retarded by the low temperature in the open. It so happened that these two effects were equal and so both treatments were retarded by an equal amount.

Table 27 also shews that at all lengths of day the plants produce more vegetative matter at the low than at the high temperatures—in the 24-hour day it is three times as great, although the retardation in ear emergence was only six days. The remarkably luxuriant vegetative development of plants grown in continuous light at low temperature is worthy of the attention of fodder experts and of physiologists. The reason for it is thought to lie in the reduced ratio of consumption and supply of food materials rather than in the difference in vegetative period.

The group of barleys which came into ear but failed to ripen includes some of those which came into ear first. This shews that it is not the insufficient time from the date of earing, but the lack of suitable conditions for growth and maturity which prevents ripening. It is more than probable that further investigation will shew the existence of other important developmental stages between the time of ear emergence and grain maturity.

Spinach runs to seed very badly in the extreme north and no strain free from this defect has yet been found. Both spinach and beet are long-day plants, but behave differently, e.g. in continuous light spinach runs to seed most rapidly at high temperatures, beet at low. In a 15-hour day spinach runs to seed at high temperature, but not at low temperature in the open. The differences between the two plants lie in their requirements in the first stage, beet requiring a low temperature, so that in the hothouse it fails to effect the first stage and even continuous light does not cause bolting. This again illustrates the principle of vernalization, that without the completion of one phase the succeeding phase cannot be effected. When grown in the open the temperature at night is sufficient to effect the first stage, and the continuous light favours the second, leading to rapid bolting. In a 15-hour day the second stage is held up and so even at low temperatures the plant again does not bolt.

Spinach, on the other hand, requires high temperature either for the first stage, which is retarded in the cold, or for the second stage. Be that as it may, it is clear that to prevent bolting it is necessary to sow beet if possible at a high temperature to avoid vernalization, and the precise temperature at which this is most successfully

achieved without prejudice to the crop is a matter for further experiment. Spinach should on the contrary be sown at a low temperature under reduced length of day, until it is discovered whether the first or second is the deciding phase in this plant.

Preliminary experiments on the same lines were done with the potato and the results are shewn in Table 28. This clearly indicates that the combination of low temperature and long day is not detrimental to tuber formation, but definitely the reverse. This again proves that conclusions as to photoperiodic reaction drawn without reference to the previous conditions of the environment may be misleading and often false; the short-day reaction of tuber formation in the potato is true only

Table 28.

	20-hour day.		10-hour day.	
	Hothouse.	Open.	Hothouse.	Open.
	Yield of tubers.			
Centifolia	1.30	103.2	19.03	50.2

at certain conditions of temperature and at low temperatures it is quite reversed to a long-day reaction. Many early varieties of potato, however, give a greater yield of tubers in continuous light at a higher temperature than at a low—e.g. Epicure gave 70 grm. in the hothouse and 28 grm. outside, and the *uninterrupted* action of low temperature, $+2$ to $+5^{\circ}\text{C}$., even for only 20 days, causes a marked reduction in tuber production, which may even be halved. It would seem, therefore, that what is necessary is a particular combination of these factors. It appears probable that combined with continuous light and intervals of high temperature suitable for photosynthesis, low temperature will reduce respiration and growth and so lead to the accumulation of food materials that will be stored in the tubers, thus stimulating tuber formation.

C.—DROUGHT RESISTANCE.

Henckel and Kolotova 101.

Drought resistance.

Various investigators have mentioned the possibility of drying seeds which have just germinated and are about to burst without impairing their germinating capacity. This process can even be repeated by again moistening the seeds and allowing germination to continue and again drying. In the present experiments wheat seeds were germinated under the conditions used for vernalization in order to retard their growth, and in this way the germinating capacity of the seeds remained unchanged after four successive dryings, provided that the drying was sufficiently thorough. The seeds were moistened during 48 hours and then dried for three days in a thermostat at $20 - 22^{\circ}\text{C}$., some once, some twice, some three and some four times. After the final drying the seeds were again moistened and sown. A control series from seed not dried at all was used.

The resulting plants were subjected to extreme wilting once at each of the vegetative phases of tillering, shooting and earing. During wilting at the tillering stage the percentage of water in the leaves was found to be higher in the plants subjected to drying, and the proportion of water lost by the plant was also correspondingly lower by 13-16 per cent. The greatest difference occurred in the plants dried three times. The plants died before maturity owing to the severity of the wilting.

The experiment was repeated in 1933, the following year, using only one, two and three dryings and less severe wilting. The results entirely confirmed those of the previous year, the loss of water being 12 - 14 per cent less in the series dried three

times than in the control at the tillering stage and 10 per cent less immediately before earing. The water content was also 20 per cent greater. The water content of the treated plants in the normal state, without wilting, was also greater than the controls and these plants exceeded the controls in yield, both of vegetative matter and of grain. It appears therefore that in addition to those factors without which a plant cannot pass to the next stage of development, according to the theory of vernalization, still other factors, not normal for the plant's development, such as desiccation, may also exert an influence on development. Whether the desiccation in this case acted in the direction of accelerated development it is not possible to say, but it certainly increased the growth of the plant and this difference in growth moreover was observed only in the later stages, which suggests that it is a developmental effect, in Lysenko's sense, caused by the treatment. The difference between the treated and untreated plants was thought to lie in the greater osmotic pressure of the former, resulting from some fundamental change in the properties of the protoplasm.

It is thought not improbable that the drying to which vernalized material is subjected may be connected with the increased yield often obtained in these experiments.

These results suggest that many factors other than the ones specified in the theory of vernalization may influence the growth and even the development of the plant. The use of strong salt solutions to retard growth as in the experiments of Bassarkaja may well be expected to have an effect on the later growth and development of the plants.

Henckel 102.

Drought resistance.

Pre-sowing hardening to drought is seen to be a gradual change in the plant under the influence of the environment, in which it would appear that the plant acquires certain new properties not hitherto possessed, since the degree of hardening increases with the number of treatments applied. The treated plants behave differently from untreated only under drought conditions and under normal conditions their greater water retaining capacity may not be manifested. The effect of pre-sowing treatment on drought resistance leads to the conclusion that not only the normal conditions necessary for plant development influence the later behaviour of the plant as stated by Lysenko, but various abnormal influences applied to the pre-sowing stage may have an equally marked effect. Thus it seems probable that the so-called normal conditions, applied at the pre-sowing stage produce an exactly similar change in the constitution of the plant and thus have an effect different from that produced by applying them at the normal time. It is even suggested that the plant at the stage of the swollen seed is in an unusually susceptible condition for such effects and this is borne out by the various biochemical changes that have been observed during vernalization. The existence of such critical phases in the life of the plant has been demonstrated by a number of other investigators.

It is pointed out that the process of vernalization subjects the plant to a pre-sowing drought for a considerable space of time and the later increases of yield observed are thought to be partially ascribable to the effect of this in making the resulting plants more drought-resistant, which effect may be obtained even in the absence of any acceleration in development.

Henckel and Nikitin 103.

Drought resistance of oats.

Proletarskii 109.

Drought resistance of wheat.

All the experiments carried out with plants subjected to pre-sowing drought treatments shewed a favourable effect of this on water content and transpiration during drought periods, on general healthiness and on the final yield. With proper

doses of water during the drought period the effect increased with the number of treatments, even up to seven times. Plants vernalized in the ordinary way were intermediate in behaviour between the control and the hardened plants.

D.—FROST RESISTANCE.

Vasiljev 113.

Frost resistance.

The rise of winterhardiness in autumn and its fall in spring cannot be explained only on the basis of those changes which occur in plant tissues in the autumn and to a certain extent in the winter. In autumn, winter plants not only undergo a process of hardening, but also find the conditions required for the completion of the thermo-stage, as a result of which the winter habit is removed and winter plants thus acquire some spring characters including a lower winterhardiness. Experiments were made in 1932 to prove this fact. Vernalized and unvernallized seeds of the plants tested were simultaneously sown in pots at the same stage of sprouting. Unvernallized seeds were germinated at a temperature of 15 to 16°C. ; vernalized seeds were chilled on ice, and then kept at a temperature of 16°C. for about 12 hours and sown. Until the day of the test all plants were grown indoors at a temperature of 15 to 16°C.

Experiment 1 was made with a non-hardy Italian wheat *Lutescens 21222* and a very hardy *Erythrospermum 118* of the Saratov Station. The plants sown on November 3rd were exposed on December 2nd to a temperature of -4 to -6°C. for 24 hours. After a fortnight the rate of survival was as follows :

<i>Lutescens 21222</i> ,	{ vernalized : all died. unvernallized : 17 per cent survived
<i>Erythrospermum 118</i> ,	{ vernalized : 64 per cent died unvernallized : all survived.

Experiment 2 was performed with the same two wheats and the wheat-rye hybrids 27/36 and *Lutescens 121*, both of the Saratov Station. The plants sown on November 3rd were exposed on December 2nd to a temperature of -5 to -6°C. for 24 hours and then kept for 4 hours at a temperature of +5 to +7°C. before returning to the greenhouse. The rate of survival 11 days later was as follows :

<i>Lutescens 21222</i> ,	{ vernalized : all died unvernallized : 3 per cent survived
<i>Erythrospermum 118</i> ,	{ vernalized : 42 per cent survived unvernallized : 92 per cent survived.
<i>Lutescens 121</i> ,	{ vernalized : all died unvernallized : 75 per cent survived
Wheat-rye hybrid	{ 27/36 vernalized : all died. unvernallized : 92 per cent survived.

Experiment 3 : the same cereals which had been sown on November 3rd were hardened in a cool light room at +4 to +7°C. from December 2nd. The plants were kept out of doors from December 19th to 27th at the seasonal temperature, which ranged from +3°C. to -11°C. with the minimum on December 27th. They were returned indoors to a temperature of +5°C. for one day and then removed to the greenhouse. On January 15th, the results were as follows :

Italian variety	{ Vernalized, all died Unvernalized 8 per cent survived.
Rye-wheat hybrid 27/36	{ Vernalized, all died Unvernalized 93 per cent survived
Lutescens 121	{ Vernalized, all died Unvernalized 75 per cent survived.
Erythrospermum 118	{ Vernalized 43 per cent survived Unvernalized 92 per cent survived.

Experiment 4 was made on the hardiest wheat variety of the Saratov Station, Lutescens 0329. This variety was sown on January 1st and grown in the greenhouse until February 28th when the plants were exposed to a frost of -15°C . during the day, removed to 0°C . during the night, and returned next morning to the greenhouse. In this case all the vernalized plants died and all the unvernallized survived.

Experiment 5: Lutescens 121 was sown on January 1st, grown as in Experiment 4, and then exposed several times to frost, on February 20th for 7 hours to -4°C ., on February 25th and 26th for 24 hours to -6 to -8°C ., and on February 28th for 7 hours to -15°C .. In the intervening periods the plants were at a temperature of $+10^{\circ}\text{C}$. After the last freezing they were left for a night at 0°C . and then transferred to a greenhouse. On March 23rd, 85 per cent of the vernalized plants had perished and the remaining plants were badly damaged, while the unvernallized were all normal and undamaged.

In order to investigate the nature of this decrease in hardiness, an analysis was made of those factors which may be to a certain extent responsible for hardiness. Carbohydrates were investigated, and the water content was estimated by drying the plants at 105°C . Analyses made of samples taken on December 8th from the plants sown on November 3rd shewed that the carbohydrate content was smaller in vernalized than in unvernallized plants. This reduction was due mainly to a fall in the hemicelluloses and monosaccharides; the sucrose content was, in two susceptible varieties (Lutescens 21222 and the wheat-rye hybrid 21/36), greater in the vernalized than the unvernallized plants, whereas in the two remaining hardy wheats, on the contrary, the vernalized plants contained less sucrose than the unvernallized plants. The water content was higher in all vernalized plants.

These experiments shewed that the winterhardiness of plants depends not only upon hardening but also on the stage of development in Lysenko's understanding of the term, and also that the completion of the first developmental stage reduces the winterhardiness of winter plants. Consequently ultra-early spring sowings of winter cereals tend to be generally less hardy because of having completed the first stage.

Buĭlina 99.

Winterhardiness in wheat.

Cereals were vernalized for the first time at the Bezenchuk Station in 1929, when seeds of five F_1 families and four F_2 families from hybrids between soft winter wheat and hard spring wheat, two alternative wheats of the Ganja Station (Hordeiforme 13071 and Apulicum 1275/118) and two hard winter wheats of the Bezenchuk Station (Leucurum 1320 and Africanum 1278) were chilled at 0 to 5°C . for 12 and 18 days and then sown on April 15. No variety eared after 12 days chilling. After 18 days chilling, Hordeiforme and Apulicum were the first to ear (May 20 and June 1),

followed by Africanum on June 11 (27 per cent earing) and Leucurum on June 18 (80 per cent earing). The hybrid varieties eared between June 8-12, producing 76-96 per cent earing.

In 1930 and 1931, 8 wheats of varying winterhardiness were chilled at 0° to 3°C. for 34, 46, 58, 70 and 82 days. It was found that for fairly complete earing the wheats of low winterhardiness (0122 and 0204 of the Crimean Station) required 46 days' chilling, wheats of average winterhardiness (Erythrosperrum 072 and 070 of the Bezenchuk Station) and some of the winterhardy varieties (Erythrosperrum 474, Lutescens 097 and Erythrosperrum 1114, all of the Bezenchuk Station) required at least 58 days' chilling, while the winterhardy Lutescens 0343 of the Bezenchuk Station required at least 70 days' chilling. Rye No. 1 under similar treatment eared completely irrespective of the duration of chilling.

In 1932 and 1933, vernalization was tested on 8 and 12 wheat varieties of varying winterhardiness. The results obtained during these years suggest the following tentative conclusions.

(a) All varieties eared more completely and the flowering period was shortened according as the duration of chilling was prolonged to an optimum figure specific for each variety.

(b) As a rule the optimum duration of chilling, i.e. duration of the thermo stage, is proportional to the degree of winterhardiness of the variety, although some exceptions were recorded.

(c) At the present time the following durations of chilling can be suggested :—

Low winterhardiness :	Erythrosperrum 0102 (Crimea)	45 days.
	Kooperatorka (Odessa)	50 days.
	Erythrosperrum 714 (Odessa)	55 days.

Average winterhardiness :	Kanred (Kansas)	55 days.
	Hostianum 237 (Saratov)	60 days.
	Erythrosperrum 072 (Bezenchuk)	55-60 days.

Winterhardy :	Erythrosperrum 1114 (Bezenchuk)	60 days.
	Lutescens 0343 (Bezenchuk) ..	60-65 days.
	Minhardy (Minnesota)	65 days.
	Erythrosperrum 1748 (Bezenchuk)	65 days.
	Milturum 2258 and 2291 (Bezenchuk)	65 days.

Timofeeva 112.

Frost resistance.

According to some investigators biological characters such as resistance to frost, drought and excessive moisture, acquisition of hardiness, etc. are closely associated with the nature of the developmental stage at which they originate and operate; hence, the estimation of plants in respect of these characters is closely related to the phasic development of plants. The author therefore investigated winterhardiness at various stages of development and with different degrees of preliminary hardening induced in plants at various stages of development and under different environmental conditions. Laboratory and field investigations were made at the U.S.S.R. Institute of Plant Industry, Leningrad, in 1933, with two winter wheat varieties (Moskovskaja 3251 and Ukrainka) and in the following year both with winter wheat (Durable, Hostianum 237, Lutescens 0329, Moskovsk. 2411, Moskovsk. 3251 and Ukrainka) and spring wheat (Hordeiforme 010 and Lutescens 062) as well as with winter rye

(Vjatka). In this preliminary report, the results obtained with the first two winter wheats only are dealt with, but the author notes that the data obtained with all nine varieties are fully corroborative.

Seeds at different stages of pre-sowing vernalization (completion of the first stage), namely, vernalized (completed the first stage), under-vernalized (at the first stage) and un-vernalized (development not yet begun) were simultaneously sown and grown subsequently under different lengths of day, namely, natural seasonal day, continuous day and short 9-hour day. Winterhardiness was investigated at different stages in plants derived from previously differentiated seeds, and also in plants with different degrees of hardening previously acquired by them at different development stages and grown under different photoperiods. The acquisition of hardiness was investigated in the beginning of winter, when plants were exposed to conditions favouring their hardening, and in spring in non-hardened plants previously grown in greenhouses. Hardiness was estimated by the percentage of plants surviving after chilling in refrigerators. The sugar content was recorded at the same time.

Table 29 shews first that the winterhardiness in plants during autumn, winter and spring varies according to development in all the variants. A sharp fall of winterhardiness in spring, in spite of favourable conditions for its acquisition and an increase in sugar, is related to the transition of plants to another stage of development. Variants 1 and 2 shew also that winterhardiness in non-hardened plants at the second stage of development, before the rudimentary ear was formed, is higher than in plants at the first stage of development. With the completion of the second stage and ear formation, winterhardiness falls sharply (Variant 3). Moreover, winterhardiness rises according as the duration of the previous vernalization had been prolonged. It is considered that hardening and the process of vernalization occur at the same time.

Winterhardiness in plants previously completely hardened is much lower at the second stage (Variant 4) than in similar plants at the first stage. In the author's opinion this is due to the fact that hardening is slowly acquired by plants at the second stage. Winterhardiness in plants at the same stage of development is closely connected with the degree of hardening previously acquired, the greater the hardening the higher the winterhardiness.

The hardiness is differently acquired not only by plants at different stages of development, but also under different photoperiodic conditions. Light has a double effect. On the one hand light, together with other factors, increases hardiness but, on the other hand, light in combination with appropriate temperature decreases it by promoting the completion of the second stage and ear formation. The low winterhardiness of plants grown under a short 9-hour day emphasizes the significance of light in the acquisition of hardiness by plants.

No correlation was observed between winterhardiness and sugar content.

The author emphasizes that the data "confirm the theory of Lysenko in pointing out the necessity for reconstructing plant breeding work with a view to obtaining more hardy forms on the basis of the phasic development of plants."

Table 29.

Variant number.	Length of day.	Stages of development.	"Ukrainka."		"Moscow 3251."		Wintering.
			Frost resist- ance.	Amount of sugars.	Frost resist- ance.	Amount of sugars.	
1.	Natural day	1st stage, non-vernalized	48		32		
		Under-vernalized ..	85		75		
		2nd stage, vernalized ..	97		70		
2.	Natural day.	1st stage, non-vernalized	77	12.9	0	13.5	
		2nd stage, vernalized	100	20.4	20	11.6	
	24 hour day.	1st stage, non-vernalized	77	22.0	3	25.2	
		2nd stage, vernalized ..	62	20.1	13	17.4	
	9 hour day.	Non-vernalized ..	11	15.0	0	10.8	
		1st stage, vernalized ..	63	21.1	12	23.8	
3.	Natural day.	1st stage, non-vernalized	58		10		
		Under-vernalized ..	69		31		
		2nd stage, vernalized ..	28		0		
	24 hour day.	1st stage, non-vernalized	100		60		
		Under-vernalized ..	100		92		
		2nd stage, vernalized ..	28		27		
4.	Natural day.	1st stage, non-vernalized	91	43.5	69	26.0	91
		2nd stage, vernalized ..	2	19.1	9	19.5	0
	24 hour day.	1st stage, non-vernalized	58	23.6	50	12.3	95
		2nd stage, vernalized ..	0	9.2	0	9.4	0
	9 hour day.	1st stage, non-vernalized	15	32.4	0	31.1	0
		2nd stage, vernalized ..	0	15.7	0	18.7	0

Variant 1. Plants non-hardened, 5 days from the appearance of young shoots to formation of the rudimentary ear.

Variant 2. Plants non-hardened, 13 days from the appearance of young shoots to the formation of the rudimentary ear.

Variant 3. Plants only slightly hardened, 40 days after formation of the rudimentary ear.

Variant 4. Plants hardened.

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Vernalization in Countries other than the Soviet Union

VERNALIZATION IN COUNTRIES OTHER THAN THE SOVIET UNION.

IRISH FREE STATE.

(41.5)

Trials were made at the Albert Agricultural College, Glasnevin, in 1934 with Wilhelmina and Yeoman II. winter wheats (25). The seed was moistened, maintained at 58°F. for 24 hours and chilled for 15 at 38°F. Part of the vernalized seed was sown on 29th March and of the remainder half was air dried at room temperature and the other half kiln dried to a moisture content of 13 per cent. Germination tests shewed that it was possible to store this vernalized seed after drying for at least a fortnight without impairing its germinating capacity. The treated plants were superior in the initial stages, but by the 23rd April no difference was to be seen and both treated and control were procumbent in habit and in strong contrast with typical spring types. On 29th May the vernalized plots of each variety began to form flowering shoots, which stage was not reached by the control plants till ten days later. The vernalized plants remained in advance of the untreated until maturity, which was reached on 31st August, five days earlier than the control. They were still however three weeks behind typical spring wheats such as Marquis, etc., and later even than the latest of the spring wheats, Red Marvel. Neither treated nor untreated compared at all favourably with the best of the spring wheats in yield. The effect of a longer period of vernalization is to be investigated.

Tests were made with steeping the seed of Wilhelmina at 60°F. for 24 hours or the period necessary to reach the required moisture content of 50 per cent. The results obtained by this method were apparently not inferior to those from the sprinkling recommended by Lysenko and the method has the advantage of greater simplicity.

An experiment was carried out to determine whether vernalization would have any effect on Spratt-Archer 37, No. 3, a very prolific and otherwise suitable barley variety, which is slightly late in ripening. The treatment was exactly as that for the wheat. After treatment the grain was sown on the 29th March alongside a control plot seeded on the same day. Both plots behaved alike during all stages of growth and ripened their grain at the same time. The treatment to which Spratt Archer 37, No. 3, was submitted was therefore ineffective in accelerating development, but it did not depress the percentage of germination of the grain.

Small samples of eleven varieties of maize and one variety of soya beans were vernalized for a period of 15 days in accordance with the technique recommended for these particular plants. Germination was adversely affected and 99 per cent of the soya beans and at least 60 per cent of the maize were killed in the process, largely owing to fungal and bacterial attack. There was no acceleration in reproduction or maturity in the treated plants.

ENGLAND.

(42)

Extensive investigations of an experimental nature have been made by Purvis

(59) on the physiology of ear development in cereals, leading to conclusions largely in agreement with those of many workers on vernalization.

The length of time required to reach earing in cereal plants receiving different experimental treatments was investigated. In winter rye one series was grown in normal long day (16 hours) and subjected to temperatures of 1°C. and 18°C. respectively, during germination, a second series was grown in short day (10 hours), with similar temperature treatments and further series with nitrogen and potash deficiencies were included. In the long-day series, cold germination reduced the length of time required for earing and flowering, which effect was not observed in the short-day plants. Low temperature in the long-day treatment also reduced the rate of tillering, an effect again not evident in the short-day plants.

Under long days and following germination at 1°C., flowering occurred 10 weeks after planting out, irrespective of manurial treatment; after germination at 18°C. it was delayed until autumn when a few ears appeared. Under short days ear emergence was indefinitely delayed after both temperature treatments. Examination of the growing points revealed that under both temperature treatments and day lengths ear initials are laid down. After germination at 18°C. flower initials are laid down *earlier in short days than in long days* and the number of initials is considerably increased, and with it the potential grain yielding capacity. Such ears, however, die within the leaf sheaths, and the stems fail to elongate. After germination at 1°C. the characteristic temperature after-effect, namely, early flower differentiation was only manifest under long days while under short days the effect was slight. When plants which had received some weeks of short day treatment were subjected to long days ears were rapidly formed after germination at 1°C. and more slowly after germination at 18°C. Even with plants germinated at high temperature, flower differentiation may be induced by short-day treatment alone, shewing that cold germination is not essential for reproduction. Stem elongation and ear emergence, however, fail unless long days are given subsequent to ear differentiation.

These results illustrate the importance of examining the time of formation of the flower primordia rather than the time of emergence of the inflorescence in studies of this kind. No effect of nitrogen or potash deficiency was observed either in accelerating or retarding differentiation in long days or in removing the inhibiting effect of short days. Neither sugar content, nitrogen content nor the carbon-nitrogen ratio were affected by the different treatments in such a way as to constitute a cause of the different flowering reactions; on the contrary these changes are consequences of flower formation.

The observations on the spike primordia indicate that a minimal number of leaves must be formed before the differentiation of flower initials can occur. Under short-day conditions this is always about twenty-two, irrespective of variety and temperature, while under long-day conditions the minimal number is less for plants germinated at low than at high temperatures, namely, 12 for the former and 22 to 25 for the latter. This reduction in leaf number combines with the more rapid elongation of the spike to accelerate the floral differentiation and to induce a behaviour more closely resembling that of spring varieties in which the minimal number is only seven. The effect of the greater minimal number of leaves required before "ripeness to flower" is attained in short days is partially counterbalanced by the higher rate of differentiation of the ear in these plants, particularly in those germinated at low temperatures. The increased rate of floral differentiation in short days also affords an explanation of the photoperiodic after-effect observed by Razumov in short-day plants like millet. However, in long-day plants like oats or barley, the floral differentiation is almost independent of day length, only the later stages being hastened by long day. All spring cereals are also of this type. On the other hand, winter rye behaves as a long-day plant only when germinated at low

temperatures. When germinated at 18°C. the floral differentiation shews the typical short-day behaviour, being promoted by short day, though stem elongation and further stages of floral development still retain the long-day reaction. Thus the effect of chilling in winter cereals sown in the spring is to reduce the minimal number of leaves required for flower initiation and enable the plant to attain the condition of "ripeness to flower" at an earlier date while long days still prevail. It is in this way that the phenomena of vernalization are interpreted.

* * * * *

Bell (4 and 5) has also made observations on the effect of vernalization treatment on English cereals. Seeds of various spring and winter cereals were treated for 7, 14 and 21 days at 3°C. and others for 7 and 21 days at 1°C. before sowing. Germination was accelerated in nearly all varieties, most of all in the spring varieties; the only variety shewing no acceleration was Joss IV winter wheat. A further series was treated also for 21 days at 3°C. and 1°C. and grown in a glass-house in such a way that no marked fall in temperature was ever experienced. This series shewed still more pronounced differences in time of germination.

At the age of 6-7 weeks all barley plants were more luxuriant in growth than the controls and in those varieties where the controls were procumbent the treated plants were more erect, especially in the glasshouse. In wheat however only one variety, Cambridge Rivett, shewed any effect at this stage. All oat varieties were more luxuriant and Grey Winter was also more erect.

The growing points were examined and proved to be more advanced both in spring and winter varieties.

An acceleration in earing was observed in the winter varieties of barley and wheat but none in the oat varieties. The difference in time of earing resulting from the treatment was much more pronounced in the plants grown in the greenhouse in all varieties with the exception of Grey Winter and Bountiful oats; and one variety of spring barley, Swan Neck, shewed a slight acceleration in the greenhouse, though none in the field. Furthermore the control plants grown in the field all came into ear before those in the house, thus indicating that the low temperatures experienced in the early period in the field had effected a partial vernalization. In the winter wheat varieties the treated plants in the field also eared before those in the house, suggesting that the period of treatment was insufficient. There are indications that treatments of 14 days were more efficient than 7 days and that 3°C. was better than 1°C.

A late sowing experiment was made with winter varieties of wheat, barley, and Grey Winter oats, which were treated for 14 days at 3°C. and sown on 28th April. No acceleration was observed in the early development but the treated plants of the barleys Bocumer, "Stadlers zweizeilige Wintergerste" and *Hordeum spontaneum* eared irregularly in mid-July whilst the controls almost or entirely failed to ear. Cambridge Rivett wheat behaved similarly, Joss IV failed to ear in both treated and control and Yeoman II wheat and Grey Winter oats eared simultaneously in treated and control.

Special attention is called to the fact that many of the varieties giving the greatest response in the early stages shewed no acceleration in earing and conversely the winter varieties with their maximum difference in earing date shewed little or no early response. It is suggested that even when treatment fails to hasten ear emergence it may result in other stimulation effects such as enhanced yield, or disease resistance. It is further pointed out that some of the earlier maturing varieties were hastened more than certain others of much later date of earing. The type of response is thus a varietal character.

Following upon the previous experiments a series of sowings was made with vernalized and unvernallized seed of winter and spring varieties of barley, wheat

and oats, one in October, 1934, and six successive ones in the following spring between 8th March and 5th April. The treatment consisted of fourteen days exposure to $+3^{\circ}\text{C}$. All varieties except the "Stadler A Wintergerste" shewed a slight acceleration in germination. The young plants were more erect in the treated lots, the difference being very pronounced in Tschermak's winter barley, where the treated plants were twice as large; the effect differed in the different varieties, being least evident in the spring varieties, Abundance oats and Spratt-Archer and Pryor's barley. The differences were also less obvious in the later sowings.

Examinations of the growing points revealed still clearer differences in varietal behaviour. Tschermak's winter barley again shewed the most pronounced differences and this was detectable at an earlier time than in the others. Thus differences between the treated and control growing points were observed after 34 days, whilst no difference was detectable in the wheat and oats till about the 70th day.

The acceleration in earing was inappreciable or nil in the autumn sowings. In the spring sowings, however, there was a progressive increase in acceleration with delay in sowing in the winter varieties and conversely, a progressive decrease in the spring varieties. This difference in behaviour is attributed to the rise in temperature with progressive lateness of sowing, in support of which view it is mentioned that greenhouse sowings (higher temperature) came into ear sooner than field sowings in spring varieties and later in most winter varieties, shewing that the low temperatures in the open had effected a certain amount of vernalization. The time required for earing became progressively less with lateness of sowing in the treated winter varieties supporting the conclusion that extension in length of day hastens earing in vernalized sowings.

Although the variety Bocumer was later than Tschermak's winter barley in shewing growing point stimulation its acceleration in earing was just as great and similarly the wheat varieties all first shewed growing point stimulation at the same time, but Rivett gave a much greater acceleration in earing.

Periodic tiller counts were made on a randomized latin square of the three wheat varieties, treated and control, and the data subjected to statistical analysis. The rate of tillering was significantly higher in the vernalized than in the unvernallized plots in the early stages, but lower in the later counts, so that ultimately the number of surviving tillers and hence mature ears was less in the treated plants of Joss and Rivett than in the controls.

Examinations of the effect of treatments of 7, 14, 21 and 28 days on Yeoman and Rivett wheat shewed 21 to be the best period; little advantage was gained by extending the treatment to 28 days. In the longer exposures $+1^{\circ}\text{C}$. proved slightly more effective than $+3^{\circ}\text{C}$.

* * * *

Experiments were made at the Agricultural Research Institute, Long Ashton, (35) with soya beans, peas (Radio) and runner beans (Painted Lady Marvel). The soya beans received 75 per cent moisture, and were treated for 24 hours at 15°C . and for 13 days in darkness at 20°C . The germination was: treated=103 plants; control=6. No seed yield was obtained as no flowers were formed, and no differences were observed between treated and control.

The peas received 1.125 pints of water to 1 quart of seed. The seeds were given 6°C . for 6 days and then darkness at 6°C . for 8 days. Germination was: treated=1475; control=804. Treated and control flowered simultaneously and the seed yields were 31.25 and 28 lb. respectively.

The beans received 75 per cent moisture and then 14°C . for 24 hours, followed by darkness at 18°C . for 11 days. Germination was: treated=112; control=106. Seed yield was 116 and 105 lbs. respectively. The seeds were sterilized with Mercuric Chloride before treatment.

* * * *

Lamberton and Parkinson (34) made a preliminary experiment on vernalization of wheat and soya bean at the South Eastern Agricultural College, Wye.

On March 27 three applications of 25 cc. water were given to 225 grm. winter wheat. The grain was exposed to 12°C. for 48 hours and stirred at intervals. The seed, in which germination was just noticeable, was placed in an ice-box; this proved to be rather unsatisfactory owing to variations in temperature from 0° to over 4°C. The grain remained in the ice-box from March 20 to April 12, when it was sown in 9 in. pots and placed in a glasshouse. Germination was: treated= 92 per cent; control=95 per cent. The control was about 72 hours later in shewing above the soil. A week later the pots were removed and placed in the open. The treated seeds produced stalks with ears some time before the control. On August 23 the ears of the treated plants were beginning to turn yellow while those now produced on the control were still green and succulent. Although the control plants were later, they were more vigorous and shewed better tillering.

In a second experiment, this difference in bulk and tillering power was again noted. It should be remembered that sowing was abnormally late owing to the treatment having been delayed beyond the desirable date. These experiments have shewn that vernalization has a definite effect on the period of fruiting, but also that it may be detrimental to the plants in other ways.

Experiments on soya beans produced healthy plants, but were used too late for flowers to be obtained.

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In experiments on vernalization of tomatoes reported by Burr and Turner (10) four groups of tomato seeds of the variety Ailsa Craig were treated on November 15, 1934 for 7, 16, 32 and 44 days respectively at a temperature varying between 1°C. and 3°C. The seeds were then stored in the laboratory and sown on January 1, 1935. It was found that the treatment had reduced germination proportionally to the length of the treatment. The treated plants lagged behind the controls in growth, fruit setting, time of fruit ripening and weight of fruit borne.

In general, the plants from seed vernalized for 44 days were most vigorous but were definitely behind the controls in weight of fruit and earliness of fruit production.

A small number of cucumber seeds of the variety Butcher's Disease Resister were similarly treated. Germination was also reduced and the surviving plants were stunted, partially sterile and at least fourteen days behind the controls.

GERMANY.

(43)

How far the use of vernalization in Germany can be extended has yet to be investigated (Feistritzer 22). Certainly by this method winter cereals can be sown in the spring and maize shews a much increased and more vigorous sprouting due to vernalization. The results on soya beans are not yet conclusive and it remains to be seen whether the method will make it possible for Germany to be independent of such imports as maize, soya beans and cotton, etc.

* * * * *

Dix (18) has vernalized both winter wheat and winter rye. Seed of two varieties of both these cereals was soaked for 24 hours in water, then transferred to a cool cellar at a temperature of 1-4°C. where it was kept for 45 days. During this period it was stirred twice. On 20th March, 1934 the treated seed was sown together with untreated seed of the same variety in four replications. The seedlings appeared

above ground on the 7th April in the treated and the 9th April in the untreated sets and a few weeks later the treated seedlings were clearly more vigorous and more advanced in growth. The difference was especially marked in the rye plants and these came into ear regularly and uniformly, only three weeks after autumn sown rye, whereas the vernalized wheat, though it was more luxuriant in growth, only produced a few isolated ears. In the untreated wheat however no ears at all were formed. The vernalized rye was harvested on the 10th August, the winter sown rye on the 26th July.

The effect of vernalization is clearly reflected in the yield figures which are expressed in centners per hectare as follows :—

Variety 2/8.					
Vernalized.			Untreated.		
		Grain.	Straw.	Grain.	Straw.
Bed a.	..	16.1	35.8	1.28	16.6
„ b.	..	22.4	43.0	1.12	19.0
„ c.	..	20.5	44.0	1.19	14.5
„ d.	..	18.1	40.1	1.12	14.1
Average	..	19.3	40.7	1.20	16.1

Variety 2/15.					
Vernalized.			Untreated.		
		Grain.	Straw.	Grain.	Straw.
Bed a.	..	18.6	37.4	1.50	17.8
„ b.	..	21.5	44.4	1.21	17.6
„ c.	..	22.0	44.3	1.55	16.8
„ d.	..	21.4	44.9	1.61	17.7
Average	..	20.9	42.8	1.50	17.5

Thus from both rye varieties the yield of straw is increased by $2\frac{1}{2}$ times and the yield of grain by 14-16 times. The fact of vernalization is thus abundantly proved. However, whether it can be recommended for German conditions is largely open to doubt. With wheat it certainly can not, and even in the case of rye the yields after vernalization are only half those from autumn sowing; and the possibility of having a period of 45 days of such a kind as to maintain the temperature of 2-4°C., neither more nor less, is always very doubtful. Thus vernalization is still regarded as a matter of some risk, but great prospects for it are admitted if by its aid it should become possible to cultivate successfully certain crops such as soya bean whose cultivation in Germany is still impossible or impracticable.

* * * * *

Klitsch (33) considers that although vernalization may be important for breeding work and general research, e.g. variety trials and phytopathological investigations, its use for treatment of crop seed under German conditions is at present attended by too many risks.

* * * * *

In experiments reported by Lowig (36) the treatment of the seed followed closely the published method of Lysenko. After treatment the vernalized seed was first re-dried and sown at a suitable time at Poppelsdorf and Dikopshof. Besides the main cereals, sugar beet was included in the experiments. The results are summarized as follows :—

- (1) An effect due to the pre-treatment of the seed was established with one exception in all the varieties investigated to a greater or lesser degree. The action was, however, very different according to the physiological nature of the variety.

- (2) Vernalization of the seed produced an advantage of practical importance in winter wheat, winter barley and sugar beets, i.e. groups whose development is interrupted by winter rest or the biennial habit.
- (3) Winter oats is always an exception and shews the same reaction as spring cereals. It is possible that it does not represent a definitely winter form but is only a more hardy variety of spring oats.
- (4) The result of the spring sowing of vernalized seed of Karsten V was a speeding up of development so that the wheat ripened in five months and with a yield equal to that of spring wheat; while from the untreated plots sown at the same time only a very few individual ears were produced and harvesting was out of the question.
- (5) Of the three varieties of sugar beet tested "Dippe W 1" gave the best results and "Westphal" the least good. With an increase in the duration of vernalization all three varieties increased the number of shoots.

While the difference in the results of vernalization between 16 and 34 days treatment is negligible, an additional 10 days shew a marked result. A sufficient duration is thus a necessity for a satisfactory action of vernalization.

The practical utility of vernalization lies first in the possibility of the sowing of winter cereals in spring if a resowing is necessary because of winter injury. And winter sowing may be given up entirely if winter injury regularly occurs.

Also, there is the possibility of hastening the vegetative period of spring wheat and of growing another crop after it.

* * * * *

Experiments have been made with Klein Wanzleben E sugar beet seed (Lüdecke 37). On 5th February, 1934 the experimental seeds were moistened with three successive doses of water, left for 24 hours at room temperature, and on 6th February both moistened and unmoistened seeds were placed in an ice chest, where they remained, with frequent stirrings, at a temperature of $+3^{\circ}$ to $+4^{\circ}\text{C.}$, until 20th March, i.e. for 42 days. The seeds were then dried at room temperature and sown on 11th April. The germination was good and equal to that of other beet varieties untreated.

Counts were made of the number of bolters on 31st July and on 4th September, 1934. Only one plant bolted, this being in the treated plot. The neighbourhood of Bernburg in which the experiments were done is very free from bolting and these negative results make the author doubt whether the bolting reported by Lowig at Bonn (Cf. p. 120) is correctly to be ascribed to the vernalization treatment.

* * * * *

Many of the South American potato species which in their natural habitat develop abundant tubers, in Germany almost or entirely failed to do so, forming on the other hand stolons of excessive length (Hackbarth 27). The specimens that behaved so proved to be those from the equatorial regions as shewn by observations of 60 different clones from varying latitudes from 0° to 45° . The photoperiodic reaction appears to be genetically conditioned, as has been shewn to be the case in certain other plants. Hybridizations have been made between potatoes of long and short photoperiod to study the inheritance of the phenomenon.

Treatment with chemicals has so far failed to alter the photoperiodic reaction but application of the principles of vernalization is likely to change the situation materially. The vegetative vigour of short-day plants grown in the long-day areas can probably be put to practical use in the case of fodder plants.

* * * * *

According to Rudorf (65) some of the direct practical advantages of vernalization for breeding are :—

(1) The flowering of early and late types together so that they may be crossed ; (2) inducing flowering for similar purposes, in plants such as short-day soya bean varieties, artichokes, etc. ; (3) in the crosses of winter and spring varieties the seed may be vernalized and all types induced to set seed ; (4) its use in winter cereals for testing rust resistance in the greenhouse before planting out ; (5) the production of several generations in the year.

Other indirect advantages are :—

(1) The use of vernalization on winter cereals etc. for testing winterhardiness. It has been found that different varieties require different exposures to cold in the grain or seedling stages before they will come into ear when sown in the spring. As a rule the varieties that require the shortest exposures to cold are also the least winterhardy.

Vernalization of 10, 20, 30 and 40 days duration followed by the usual methods for the direct application of cold has shewn that there are varieties which come into ear when sown late in the spring but which shew also a characteristic cold resistance. The Argentine variety, Lin Calel, is an example.

(2) The effect of the treatment, and especially the effect of length of day on the physiology of tillering of winter and summer cereals. The long day of spring tends in the long-day plants to a much hastened development at the expense of tillering and growth and leads to a diminished yield. The aim should be to breed more neutral plants without completely losing their other long-day characteristics. For forage plants too this point of view needs consideration.

(3) The testing of such short-day plants as soya beans, tobacco, hemp, maize, melons, etc., with the object of discovering, if possible, strains which are either neutral or even possess to a slight degree, long-day characteristics.

As the long or short-day characters as well as the cold or heat requirements in certain phases of development are genetically determined, breeding for the desired characters becomes a practical possibility.

* * * * *

The same author (Rudorf 64) considers that one of the main obstacles to the cultivation of the soya bean in Germany is the fact that it is a short-day plant and so unsuited to the long-day conditions of the growing season. It has, however, been found that all varieties of a species do not necessarily shew the same reaction to length of day but many included long-day, short-day or neutral types.

Several varieties of soya beans which shewed differences in the length of their growing period were grown under short-day conditions to test their reaction to subsequent long-day conditions. It was found that there were very considerable variations among the varieties in the amount of shortening of the time taken before flowering and that in general the varieties which under long-day conditions took longest to flower shewed the greatest shortening of their period as the result of short-day treatment.

It is, however, denied that the earliest varieties in general shew the least reaction to short-day conditions and it is still hoped that further researches will reveal the existence of long-day or at least neutral strains of soya beans.

Nine varieties of *Phaseolus vulgaris* were similarly tested, among them a number of varieties markedly short-day types, Beste von Allen, Non plus ultra and Englische Gelbe with a less marked short-day reaction, the neutral Reis-Perl and the slightly long-day type Konservanda. It was found that the short-day conditions did not produce so marked an effect as in the soya beans.

* * * * *

Another study by Rudolf (62) was concerned with the concept of earliness in spring cereals and peas and the photoperiodic reaction of wheat from different geographical latitudes. This study was divided into two parts as follows:—

(a) Experiments were made on the course of development in long-day plants under the influence of different conditions of germination and on the meaning of earliness from which it is concluded that early varieties of spring cereals and peas are those that have a short total duration of development from germination to maturity. Within the total course of development they require very little time up to the onset of the reproductive phase; while the development of the grains or fruit and its ripening under varying conditions takes an absolute and relatively longer time than in the late ripening varieties.

(b) Observations were also made on the action of photoperiodism on spring varieties of wheats from different geographical latitudes, from which it is shewn that earliness and reaction to photoperiodism is not one character but two independent characters. It might readily be supposed from results on spring wheats from such a pronounced long-day region as Canada that these would all respond to changes in photoperiodism. Exceptions are furnished however by Reward and Garnet, the earliest varieties of all, which yet shew the least response.

* * * * *

Rudolf and Stelzner (63) undertook experiments with a view to the improvement of lettuces by increasing the time during which they are of market value.

Varieties for forcing and winter and spring varieties were used, two typical kinds of each, and were sown at the end of June, some with a normal light period of 16½ hours, others with 12 and 8 hours light periods respectively for 12 and 24 days. A series grown for 14 days in complete darkness died.

The two spring varieties and one winter variety proved to be uninfluenced by changes in the light period. In the other varieties the shortday noticeably decreased shooting in the plants. It was also found that there was a considerable increase in organic mass in the plants grown under short-day conditions.

In practice therefore the young plants should be grown under short-day conditions and so increase the length of time when they are of market value.

Experiments were also made on the effect of temperature. Seed of all the varieties was germinated at 25°C. and the seedlings then grown for 10 days at either —5°C. or +5°C. in the dark. Treatment at —5° led to a marked increase in the fresh weight and marketing value of the plants in all except one variety.

CZECHOSLOVAKIA.

(437)

Experiments have been made at the Seed Testing Station of the Institute of Agricultural Research, Brno, on various thermophilic plants, including millet, Sudan grass, sorghum, soya beans, corn, peanut, cotton and melons (15). Positive results were obtained in cotton when the technique was applied to young plants and not to germinating seeds. In winter cereals some varieties shewed no reaction even after 30 days treatment, while others developed simultaneously with spring varieties after only 15 days treatment.

Vernalization is being applied in seed testing to determine the varietal purity and authenticity. The influence on monoecious and dioecious plants is also being studied.

Positive results from vernalization have been obtained with certain grasses.

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Chmelar and Mostovoj (14) tested whether a chilling of pre-germinated seed of three red clover varieties (which in a former experiment gave a different photoperiodical reaction) would shorten the vegetative period of plants grown from this seed. The method used was the following : seeds slightly pre-germinated at 18 to 20°C. in the dark were kept for 15 and 30 days in a room the temperature of which fluctuated between 0.5°C. and 2°C. The seeds together with a control were then planted on trays in rows 2 cm. apart and 1 cm. wide. The plants were grown under permanent light for 30 days. The permanent light arrangement has been described in *Herbage Abstracts*, 4. 100. 1934. Results obtained shewed that chilling of pre-germinated seed had no influence on the vegetation rhythm of the red clover varieties tried. The photoperiodical character of the examined varieties remained unchanged. It has now been found that the early form had an unbranched root with few nodules, but the single cut form had a branched root system with many nodules. The authors stress again the importance of using permanent light for distinguishing single and double cut varieties and for testing the uniformity of varieties. Under permanent light it is possible in a short time to select clover plants with different leaf forms, less pubescence and a more fleshy stem, etc. By transplanting the selected plants in open ground later, the red clover breeding work could be made more rapid and efficient. Some plants with striking characters (gigantic and dwarf growth) were isolated for further observations.

POLAND.

(438)

According to Starzeński (69) the vernalization of soya beans, *Lupinus albus*, maize, hemp, sunflower, cotton and *Ricinus* may be of some importance for Poland where Professor Lewicki at Pulawy is studying its application.

* * * * *

Chroboczek (16) made investigations on the causes of bolting in beet. Young plants were grown in a greenhouse at 15.5-21.1°C. from seeds sown at intervals of 10 days. In autumn (1st November) the plants from all series were divided into cold (10-15.5°C.) temperate (15.5-21.1°C.) and hot (21.1-26.7°C.) conditions. Half of them received normal daylight and half received additional electric light up to 10 p.m. All plants grown in the cold formed flowering stalks on 14th May, the plants receiving additional light being earliest (January 27th). It is evident that a low temperature of 10-15.5°C. is able to cause shooting and that freezing is not necessary. At the high temperatures, however, even under long day the plants did not develop flowering stalks. The influence of cold was greater in the older plants and in the young stages it had no influence at all on stalk formation. At high temperatures the author was able to grow the plants for as long as two to three years vegetatively, yet when they were put into a cold greenhouse they readily formed flowering stalks. Plants that had produced seed once formed new stalks when grown further in the cold; those in the warmer temperatures developed vegetatively. If conditions were changed during stalk formation, the plants began to grow vegetatively; cuttings from a plant reacted similarly to the plant from which they were taken. Beet plants grown in the open corroborated the findings in the greenhouse.

FRANCE.

(44)

Schribaux and Friedberg (66) discuss the possible value of vernalization under French conditions. From a series of experiments with 18 types of wheat at the Station Centrale d'Amélioration des Plantes at Versailles, it is concluded that ver-

nalization might be of use where extremes cold has destroyed the autumn sowing, provided sufficiently low temperatures occurred in January and February. A comparative test of vernalized and spring varieties is in progress.

Vernalization could be used to determine the capacity for very late earings in the lines derived from a cross.

ITALY.**(45)**

Of four varieties of wheat tested in Italy (Munerati 47) only one, Inallettabile Vilmorin, responded successfully to the treatment. The plants from the treated seed were more susceptible to rust than the controls. It is suggested that the climate of Italy is not favourable for the treatment and further investigations are needed to explain the differences observed between varieties in their response.

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Jannaccone (31) after describing Lysenko's method and the results of vernalization in other countries concludes that its only possible advantage in Italy would be to enable spring sowings to be made when winter sowings have been destroyed, and in breeding and genetic work. Vernalization will only assume a real importance for Italian agriculture if it is demonstrated that the method gives a better and greater yield than that obtained now from the spring sowings.

PORTUGAL.**(469)**

The importance of early maturity in regions of irregular rainfall is emphasized by Camara (11). After describing the method and stating the great possibilities of vernalization, the author points out the necessity for strictly defined conditions.

SWEDEN.**(485)**

According to the Report for 1933 of the Luleå Chemical-Plant Biological Station (38) a vernalization trial on a small scale was initiated during the summer at Hagalund. The cereals included were: Oats: Orion II and Great Mogul; barley: Vega and Kenia; spring wheat: Aurora and Extra Kolben II; autumn wheat: Ankar II. The vernalized plots shewed generally slightly earlier establishment and panicle emergence. The difference, however, in comparison with the untreated plots was so trifling that it could only have been contingent upon pre-germination in the treated plots. No difference in time of ripening could be ascertained. Neither did the autumn wheat during the summer proceed further than the grass clump stage in spite of the fact that several samples which had been subjected to cold treatment for varying periods were included in the experiment.

No direct pronouncement can be made concerning the value of the method on the basis of this limited material. Different varieties are said to react differently, and according to information received satisfactory positive results have been obtained in experiments at other places with certain varieties of autumn wheat.

* * * * *

According to Åkerman (2 and 3), experiments were to be instituted in Svalöf in 1934 to ascertain the applicability of vernalization to Swedish varieties. The method was considered to be of value locally for obtaining several generations per year and for extending the area of cultivation of good but late varieties.

An article on these experiments has appeared in a Portuguese journal (Pires 57), but the following remarks are taken from information supplied by Professor Åkerman.

Only one trial on vernalization was made at Svalöf in 1934. This experiment was made with two varieties of spring wheat, Svalöf Diamant and Svalöf Extra-Kolben II. No visible results were obtained.

The 1935 experiments have been considerably extended. The experience is that the results depend largely on varieties used and the duration of treatment. Positive results have been obtained with winter barley and winter rye.

The experiments were carried out by G. Andersson ; no results will be published until further experience is gained of the application of the method to Swedish varieties.

HOLLAND.**(492)**

Experiments have been made by van Hoek (29) on van Hoek spring wheat, three varieties of soya bean, *Sorghum exiguum* and Red Star potatoes.

The wheat was treated in the way described in the Bulletin of the Imperial Bureaux of Plant Genetics and other early publications, chilling being carried out in an ice chest at 3-6°C., one lot for 7 days and another for 16 days. The results were as follows :

37 days vernalization
at 3-6°C.

		Untreated
1st March	date of sowing	31st March
7th April	beginning of emergence	9th April
484 plants	number of plants emerged on 10th April	205 plants
19th April	beginning of tillering	22nd April
1	number of ears fully visible on 25th June	0
14	" " " " " 26th "	1
130	" " " " " 28th "	55
28th June	average beginning of ear emergence	29th June
8	number of ears in flower on 30th June	2
80	" " " " " 2nd July	22
3rd July	average beginning of flowering	4th July
16th July	end of flowering	17th July
23rd August	harvested	23rd August
8.49 cm.	mean length of ear	8.06 cm.
46.108 grm. $\pm$ 0.23	mean 1,000 corn weight.	44.334 grm. $\pm$ 0.3.

This shews that the germination was more rapid in the treated seeds. The size of the plants was greater, especially in the early stages. In the average beginning of earing and flowering, the treated plants were a day ahead, much more so in the time at which isolated plants began. Both lots were harvested on the same day for practical reasons, but there was a difference in maturity of about four days, judging by the colour of the straw and the consistency of the grain. The ear length was taken as the average of 100 ears, the thousand corn weight was determined on 10 $\times$ 1,000 grains. The difference of 1.774 grm. $\pm$ 0.41 in thousand corn weight is significant.

The results for the 16 day treatment were as follows :—

16 days vernalization at 3- 6°C.		Untreated.
9th April	date of sowing	9th April
15th April	beginning of emergence	17th April
30th April	beginning of tillering	1st May
1	number of ears fully visible on 29th June	0
6	" " " " " 30th "	0
37	" " " " " 2nd July	0
59	" " " " " 3rd "	3
80	" " " " " 4th "	15
4th July	average beginning of ear emergence	7th July
10	number of ears in flower on 5th July	0
42	" " " " " 7th "	10
8th July	average beginning of flowering	10th July
21st July	end of flowering	27th July
23rd August	harvested	23rd August
8.13 c.m	mean length of ear	8.08 cm.
41.556 gm. $\pm$ 0.43	mean 1,000 corn weight	40.567 gm. $\pm$ 0.30

Some of the vernalized plants were damaged by mice immediately after germination. The difference in size was much more pronounced than in the shorter treatment and in this case the treated plants were 3 days before the control in date of average earing. In maturity they were estimated as 1-4 days earlier.

Number of ears in each length group.

Length of ear.	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0
7 days vernalization..					3		8	14	25	24	42	36	30	10	4	4		
Untreated ..			1	5	3	11	12	22	21	27	36	20	30	9	2			1
16 days vernalization..		2	3	7	4	12	9	6	17	29	32	40	21	13	4	1		
Untreated ..	1		5	6	6	11	8	7	21	34	27	29	28	12	4	1		

The above frequency distribution shews that the length of ear was also increased, the greatest number being in the length group 8.75—9.25 in the 16 days treatment and in the 7.75—8.25 group in the control. In the 7 days treatment the modal number was the same but there were more plants in the group 8.25—9.25 in the treated than in the control plants.

The lower ear length and thousand corn weight in the second treatment are ascribed to the loss of the best plants by the mouse attack.

From the results it is clear that the longer treatment is the more successful and it is desirable that still longer treatments be tried.

The soya beans were treated for 10-15 days in the dark at a temperature of 20-25°C. after moistening with 75 grm. water to 100 grm. seed at a temperature of 10-15°C. Difficulty was experienced with fungus attack and the germination of the seeds and it is suggested that this might be obviated by slightly drying them.

A variety obtained from Vilmorin germinated with difficulty after the treatment but Java soya varieties germinated excellently, the moistening having been effected in this case at intervals instead of all together before treatment. Neither treated nor untreated plants flowered, the treated being less vigorous vegetatively however, possibly indicating a greater approximation to the reproductive phase than the untreated plants. Possibly the treatment was either faulty or unsuitable for the particular varieties used.

The sorghum was treated for nine days at 30°C. in the dark, after moistening with 26 grm. water per 100 grm. seed. Drying was necessary here also and the treated seeds germinated badly. The treated plants later tillered vigorously and reached the same height as the controls; they seemed to be later in maturity than the controls however.

The potatoes were suspended, after removal of the sprouts, in a box fitted with a Philips projection lamp of 500 W in an aperture in the lid, at a distance of 55 cm. from the tubers. The bottom of the box contained a mirror. By adjusting the position of the lamp in the aperture the temperature was maintained at 18-20°C. The tubers were treated for 26 days. The sprouts appeared above ground 10 days after planting, the untreated being a day earlier than the treated. The latter however grew more rapidly and vigorously and the foliage died sooner, on August 25th as against August 31st in the controls. The yield from 23 plants was 22.270 kg. in treated and 20.624 kg. in controls and the tubers were also larger. The control field received slightly less sun but the author is of the opinion that the vernalization was at least partly responsible for the difference in yield.

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Experiments with Robarello rice have been made by Ossewaarde (50). Seedlings were maintained for two weeks after germination at a temperature of 3-5°C. Another lot was kept at this temperature for five weeks and a control without temperature treatment. The treatments were carried out at such a time that all seedlings could be planted out simultaneously on April 14th, 1934. By April 27th the leaves of the two treated lots had reached a length of 16 cm. while the controls were only 8 cm. Tillering began in the two treated sets on May 9th and on May 15th in the control. The plants of the two weeks treatment were 2-7 days earlier in flowering than the control, the five weeks treatment being intermediate. Flowering was completed more rapidly in the treated plants. The time of ripening shewed similar differences. The yields of grain and straw were greater in the two weeks treatment by 18 and 14 per cent respectively, but the five weeks treatment resulted in an actual diminution in yield. The yield increase in the shorter treatment was brought about by a greater number of panicles and a greater number of mature grains per panicle; the grain length was slightly less, resulting in a somewhat lower thousand corn weight.

* * * * *

Elema (20) does not expect that vernalization will have great practical application in Holland, although it is of undoubted theoretical significance. Experiments at Groningen have demonstrated the difference in reaction of different varieties and at Wageningen it has become evident that different varieties require different temperatures for successful treatment and that these must be applied for varying lengths of time.

On 15th December, 1933, J. Semmelink treated moistened seed of Juliana wheat and Petkus rye by exposing it to a temperature of 2-4°C. in an outhouse, the temperature being controlled by opening and closing the windows. The treatment lasted for six weeks, till February 1st, 1934. The author sowed the seed on April 1st, together with controls of untreated seed.

The treated plants at first developed somewhat more slowly, probably owing to the seed having been dried before sowing. A little later however enormous differences in favour of the treated plants were observed in the rye, the untreated plots of which remained in the grass-clump stage whilst the treated plots went ahead normally just like spring rye. A few of the control plants formed small ears very late in the season whilst all the vernalized plants came into ear normally.

The effect of treatment in the Juliana wheat was of a similar type though very much less pronounced than in the rye, so that not even all the treated plants produced mature ears.

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Experiments of a preliminary nature were made in 1934 at the Department of Crop Cultivation of the University of Wageningen (Mayer Gmelin and van Rees 26). The crops used were winter wheat, summer wheat, maize, soya beans, millet, sorghum and fodder beet.

Winter wheat. The varieties used were Wilhelmina (slightly frost-resistant) and Robusta (highly frost-resistant). Seeds were soaked for 30 hours at the rate of 33 grm. water to 100 grm. of seed at 10 to 15°C. The grains were then kept in an almost closed vessel at 3 to 4°C. for 45 days, and sown immediately after this period. Germination and early growth were normal. Shooting was earlier in the treated plots. The ripening of the vernalized plots was irregular; the Wilhelmina was better than the Robusta. There was also a distinct influence on the development of the plants, especially in ears and seeds.

The method is suitable for the artificial acceleration of earing and seed formation in wheat, although it would not appear yet to have any practical significance in Holland.

Spring wheat. Seeds of the varieties van Hoek and Heine's Kolben were soaked as for winter wheat and then kept at 3°C. for 14 days. No acceleration was obtained.

Maize. Four varieties were tested (1) Virginia Dent corn, (2) Pettender corn, (3) Jaune des Landes, and (4) Blanc des Landes. The first is a late variety which ripens few or no seeds under local conditions; the last is an early variety which generally produces abundant seeds. The other two are intermediate.

Seeds were soaked for 24 hours at 14 to 15°C. in water supplied at the rate of 30 grm. per 100 grm. of seeds. The samples were then kept in darkness for 12 days at 21 to 23°C. Germination continued during this period, so that, at the end, the roots were some centimetres in length and the seeds were difficult to sow. Moulds also limited germination.

Pollen shedding was 1 to 2 days earlier in the treated plots, but otherwise there was no significant difference.

Soya bean. The two varieties of *Glycine hispida* used were (1) Yoshioka chiruriu (early) and (2) Type A.S. from Dieckmann (Heimburg Harz., Germany) as a late variety. The first generally forms flowers, but not the second. Seeds of both varieties were soaked for about 24 hours at 14 to 15°C. in water at the rate of 75 grm. per 100 grm. of seed. The samples were then treated with darkness for 12 days at 21 to 23°C. The same difficulties were experienced as with maize.

No significant results were obtained.

Millet. Seeds of Japanese millet (*Panicum italicum*=*Setaria italicum*) were soaked at 14 to 15°C. for about 24 hours at the rate of 26 grm. water to 100 grm. of seed. Samples were then kept in darkness at 25 to 30°C. for 5 days. Germination was poor and results insignificant.

Sorghum. Seeds of *Andropogon sorghum* and *Andropogon sorghum saccharatum* were soaked at 14 to 15°C. for about 24 hours in 26 grm. water per 100 grm. seed. The samples were then kept in darkness for 9 days at 20 to 30°C.

No significant results were obtained.

Fodder beet. An attempt was made to force beet to reach maturity in the first (sowing) year. Seeds of Barres Strynö beet were soaked for half-an-hour in running water at 23 to 25°C. and kept for germination for 2 days at 20°C. The seeds were then vernalized at 3° and 10°C. for 5 and 10 days, but results were negative. Further trials will probably be made with longer periods of treatment.

GREECE.**(495)**

Papadakis (51 and 52) has reported experiments made in Greece which in many ways confirm the phenomena of vernalization.

Ten varieties of wheat were sown at 15 day intervals from 17th February to 1st June. The results shew that each variety has a date of sowing which ensures the shortest period "sowing-earing." Sowing before or after this date increases the length of the period.

Both spring and winter varieties require a certain degree of cold in the early stages to produce earing.

The results of mixing the seed of different varieties of wheat with ice and keeping it in an ice-chest for a number of days shewed that : the treatment of the seed by cold accelerates earing not only of winter, but also of spring wheats. There is great variability in the degree of cold required to produce earing among both spring and winter varieties.

The earing of all the varieties tested is retarded by limiting the duration of the illumination.

BULGARIA.**(497.2)**

As a result of an investigation made by P. Topalov on the response of the chief Bulgarian wheats to pre-sowing vernalization, they can be divided into three groups (1) winter wheats, such as Nos. 0.12, 0.36, 0.10, 68 and 16, which shew no response to vernalization ; (2) wheats such as Nos. 0.55 and 0.110 which respond only slightly ; (3) wheats such as Nos. 0.11, A.106, A.12, A.122, A.140 and 159 in which vernalization produces a marked effect in quality and quantity of yield, and in length of vegetative period. The present review is an attempt to summarize the results concerning the third group of wheats only.

Experiments on vernalization of winter wheats were conducted at the Experimental Station, Sofia, in 1933 and 1934 (71). The same winter wheats were vernalized at the same temperature, but for a different number of days, as the experiments were intended to establish the response of each variety to vernalization and the optimum number of days required for each variety.

The seeds were moistened at a room temperature of 15°C. and vernalized at 0° to 3.8°C. for 15, 21, 26, 32 or 40 days, the seeds were then dried and stored until sowing. In 1933 sowings were made in pots on April 5, and in 1934 on March 25 ; in field trials sowings were made on March 10 ; control pots and plots were sown with unvernallized seeds in the previous autumn, at the normal date used in Bulgaria. Field experiments had three replications.

The belief that vernalized plants develop more rapidly than the unvernallized was not confirmed. During the first days no difference was observed in development between vernalized and unvernallized sowings of the same variety, but the tillering of unvernallized plants seemed even more vigorous. The delay in the development of vernalized plants during the first period of growth may be attributed to a preliminary moistening of seeds, i.e. the increased sugar content due to moisture influenced both germination and subsequent development. This is supported by a chemical analysis of seed samples made before sowing by M. Stefanovskii, who found that with increase in water content the percentage of sugar is increased and that of starch is decreased ; in vernalized (moistened) seeds more sugar and less starch were found, and in unvernallized (unmoistened) seeds conversely.

The vernalized seeds were normal in germination. Difference in development between vernalized and unvernallized plants was observed only after shooting. All vernalized plants developed more rapidly than unvernallized plants, although to a varying extent. Thus, winter wheat No. 0.11 sown unvernallized on November 20, produced seedlings on November 30 and eared on June 20. The same wheat sown vernalized on April 5 eared on July 4, i.e. 14 days later, whereas seeds sown unvernallized in spring did not produce ears. Winter wheat No. 40 after autumn sowing appeared simultaneously with No. 0.11 and eared on June 27, while the same wheat after 30 days' vernalization eared on July 4, i.e. simultaneously with the vernalized plants of No. 0.11 and the unvernallized No. 40 produced only one ear with a few under-developed seeds. Similar results were obtained with other wheats in the 1933 experiments, namely, unvernallized plants sown in autumn on November 20, produced seedlings on November 30 and eared on June 20 (early) and 27 (late), whereas when vernalized and sown on April 5, they produced seedlings on April 16 and eared on July 4 (Nos. 0.11, 40 and A.12), July 6 (Nos. A.106, A.122 and A.140), and July 10-16 (Nos. 0.55, 0.110 and 68) respectively. The pot experiments in 1934 gave similar results, namely, vernalized sowings eared later than autumn-sown unvernallized seeds. The delay in number of days was similar, although in 1934 sowings were made 10 days earlier (March 25) than in 1933.

It is of interest to note that when the winter wheat No. 159, tested only in 1934 both in pot and field experiments, was sown unvernallized in spring it eared only 12 days later than the vernalized plants and 22 days later than when sown unvernallized in autumn. This is explained by the author as being due to the fact that it is a hybrid between a winter strain and spring wheat, *T. vulgare* var. *lutescens*, i.e. it possesses some of the hereditary properties of a spring wheat.

In the 1934 field experiments the sowing on March 10 was comparatively early. For instance, in 0.11 autumn-sown on October 27, seedlings emerged on November 5 and eared on May 20. In the same wheat sown vernalized on March 10 seedlings emerged on March 29 and eared on June 6. Spring unvernallized sowings of the same wheat gave a few scattered ears; some ears yielded a few undersized grains. No. 40 when autumn sown eared on May 27, and the vernalized spring sowing (March 10) of the same wheat eared on June 6. Unvernallized spring sowings of the same wheat had partly eared by June 30. No. 159 when autumn-sown eared on May 20 and when vernalized on June 4. Spring unvernallized sowings of the same wheat eared on June 18. Similar results were obtained with A.122 and A.140. On the whole, vernalized sowings ripened 10-12 days later than autumn unvernallized sowings of the same wheat.

Hence, both pot and field experiments shewed that vernalized sowings ear and ripen later than unvernallized autumn sowings. This is probably due to the late seedling emergence on account of spring drought. It can be assumed that earlier sowings of vernalized seeds would produce earlier seedlings and that earing and ripening would then be, if not earlier, at least not later than in unvernallized autumn sowings. In any case, if the length of the vegetative period is calculated for unvernallized autumn and vernalized sowings, it will be found that the vernalized plants completed their development in a shorter time than the unvernallized. Thus, in wheat 0.11, the period from sowing to ripening was 200-220 days, and in the same wheat vernalized 120-130 days. It may be noted that No. 40 when autumn sown eared one week later than No. 0.11 and when vernalized eared simultaneously with it.

In the pot experiments of 1933 and 1934, vernalized seeds produced smaller plants than unvernallized sown in autumn, which is probably related to the length of the vegetative period. On the other hand in the 1934 field experiments, the vernalized plants were taller than those sown unvernallized in the autumn. This can be explained by the fact that in pot experiments both control (unvernallized seeds

sown in autumn) and vernalized plants were grown throughout with similar soil humidity, whereas in the field experiments soil humidity depended on the rainfall which occurred when the control and experimental plants were at different developmental stages. Tillering in the vernalized plants was also more vigorous with a consequent increase in vegetative growth.

No. 40 vernalized for 30 days in 1933 gave a larger yield of grain than when autumn-sown unvernallized. No. 0.11 and A.106 vernalized in the same year for 30 days gave a grain yield practically equal to that of unvernallized autumn sowings. The pot experiments of 1934 gave similar results. The remaining varieties in the experiment were only slightly, or not at all, affected by vernalization. Either the properties of the varieties are such that they cannot be influenced by vernalization or they require a different set of environmental conditions.

Different results were obtained in the 1934 field experiment which should be more reliable than the pot experiments, since plant development in the field occurred under natural conditions, particularly in respect of soil humidity. A fall in temperature in April was such that the seeds sown could undergo a second vernalization with the result that some spring unvernallized sowings produced ears, e.g. No. 159. Owing to spring drought, the greater part of the seeds sown vernalized and unvernallized in spring had not germinated and the stand was very poor. At harvest the following number of plants of No. 0.11 was found per sq. metre: on unvernallized autumn sowings 298 and on vernalized plots 134 to 140. In No. 40 the figures were 302 and 152-159, and in No. 159, 290 and 140-150. In order to obtain a reasonably clear idea of the yield from vernalized plants during a normal growing season, 100 plants at similar stages of development were taken from each plot and used both for morphological investigation and estimation of yield.

The total weight of the plants in vernalized wheats was higher, since tillering in the vernalized plants was favoured by the warm spring, and vernalization alone also increased tillering. The yield of grain of the vernalized plants was however reduced, resulting upon a reduction in thousand-grain weight. Probably the short vegetative period prevented the vernalized plants from producing fully developed grains.

Under Bulgarian conditions it was thus impossible to obtain positive results. The main inhibiting factor is spring drought, which does not permit the spring sowing of vernalized seeds of winter forms. The vernalization of winter wheats has no practical significance, for all favourable conditions for normal autumn sowings are to be found there. A reduction of the lengths of the vegetative period should be made not by vernalization, but by the appropriate selection and breeding of early strains. Nevertheless vernalization may be of exceptional importance for spring sowings. If vernalization makes it possible to obtain plants ripening at least 10 days earlier, the adverse effects of the summer drought will be avoided. It is for this reason that efforts should be made to establish the response of different spring varieties to vernalization, as well as to find suitable duration and temperature to be used.

RUMANIA.

(498)

Experiments were made by Piescu (55) on ten winter and five spring wheats and seven barleys of Rumania, four German winter wheats, six winter and one spring wheat from Sweden, two American winter wheats, three winter and two spring wheats from Russia and one Danish winter wheat.

The grain was vernalized and plots were sown as follows: *a*, control plants sown in the spring; *b*, plants from vernalized seed sown in spring, and *c*, winter varieties sown in the autumn.

The majority of the winter cereals from vernalized seed developed the habit of spring plants. Some foreign varieties from maritime climates behaved like winter cereals sown in the spring.

The vernalized plants *b* headed some days later (according to the variety) than the control plants *c*. The *a* plants headed about ten days after the *b* plants. The vernalized spring varieties headed at the same time as the control *a* plants.

Data are given on the date of harvesting and the yield of the three groups, from which it appears that some, but not all, varieties respond successfully to vernalization.

A later report (Piescu 56) deals with maize; results are inconclusive, but there were indications in favour of the treated plants.

CHINA.

(51)

Shen (67) has published a preliminary report of a wheat vernalization experiment. Seventeen varieties were used, 13 being winter varieties from North China. All varieties were treated in the following ways:

(A) Seed germinated for 24 hours at 50°-60°F. on 10th February, 1934, then placed in a refrigerator at 38°F. for 48 days and planted out on 31st March.

(B) Similar to A, except that the seed was kept out-of-doors at an average temperature of 46°F. from 10th February to 31st March.

(C) Seed was germinated on 30th March and planted the following day.

(D) Seed was sown on 31st March without any previous treatment.

Results.

In (A) and (B) the period from sowing to heading was 131-145 days shorter than the control sown 20th October, 1933. There was practically no difference between the results of treatments (A) and (B).

Only six varieties from (C) headed and these not till the beginning of July.

Only one variety of (D) headed. This was an early variety.

Taking this early, untreated variety as a standard, 12 of the 17 varieties vernalized headed earlier and all shewed an increased yield.

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At Nanking, rice was treated in darkness for 15 days in a solution of K_2HPO_4 at a temperature of 19 to 25°C. No differences were observed.

INDIA.

(54)

In a general review published in the *Madras Agricultural Journal* of 1935, it is stated that results in India have not so far been very promising. The following items will indicate the degree of success obtained in experiments in different parts of the country.

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At the Imperial Institute of Agricultural Research, Pusa, two varieties of wheat, of barley and of oats were soaked and treated at a temperature of 0-4°C. in an ice chest for one and two weeks, with controls soaked to bring the embryo to the same stage of development as that of the treated seed (60). No difference in yield or maturity was observed in wheat. In barley, treatment for one week accelerated maturity by 4.42 and 0.11 days in the case of Type 21 and Type 2 respectively, the former difference being significant. Treatment for two weeks retarded maturity by 2.49 and 11.92 days in Type 21 and Type 2 respectively, the difference being significant. In oats, treatment for one week accelerated

maturity by 6.07 and 3.02 days in B.S.I. and Iowa 103 respectively, the differences being significant. Treatment for two weeks accelerated maturity by 6.69 and 1.48 days in B.S.I. and Iowa 103 respectively, the differences being significant. The results so far obtained are not sufficiently conclusive to indicate whether vernalization is likely to form a feasible method for applying on a large scale.

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At Indore a technique is being evolved for cotton, but the method is not considered to be commercially applicable under local conditions (30).

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The Department of Agriculture, Nagpur (48) reports trials with cotton and sorghum. When treated according to Lysenko's directions, no definite results were obtained.

In another series, sorghum seeds were kept, after soaking, for ten days at 15°C. and in darkness at 13°C. Accelerated germination was observed in those treated at room temperature; less in those at 15°C. An acceleration of 4 days in the 15°C. variant and of 3 days in the 13°C. variant was observed in maturity. Growth was more vigorous in the former.

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Experiments are in progress on the vernalization of cotton in Surat (70).

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The Millets Specialist, Agricultural Research Institute, Coimbatore, has made observations upon sorghum, *Panicum italicum*, *Eleusine coracana*, and *Pennisetum typhoides*. In view of the diversity in time of ripening of the local varieties no results of practical value are anticipated (17).

Cambodia cotton was treated at 28 to 30°C. for 5 to 6 days. The Russian methods of retarding germination were found to be unsuitable and seeds suffered from fungous attack, germination being impaired.

Rice seeds were vernalized in darkness at 29 to 30°C. for 5 to 30 days. Germination was unaffected and the acceleration was nil. A modified technique is to be tested.

Results with sorghum, *Panicum italicum*, *Eleusine coracana* and *Pennisetum typhoides* were inconclusive. Growth of moulds in these seeds was prevented by Ceresan.

Experiments are in progress on the application of Lysenko's technique for short-day plants to sugar-cane cuttings.

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At Poona (58), trials with wheat and sorghum were made, using the Odessa technique, with variation in temperature. No acceleration was obtained. Experiments with cotton and cereals are in progress.

CEYLON.

(548.7)

Vernalization experiments have been made by Haigh (28). Seed of five varieties of maize was soaked for 24 hours in water in the proportion of 30 grm. water to 100 grm. seed and kept in darkness for 11 days at 25°C. Damage by moulds, etc., was experienced in spite of sterilization with mercuric chloride. The period sowing to opening of male flowers was 63.9 days in the treated and 63.3 in the untreated and the period from sowing to the appearance of silks was 72.1 days in the treated and 69.2 in the untreated. There was no acceleration therefore as a result of the experiment.

Rice seed of two varieties was treated in a number of different ways, namely :—

- (a) Seed sown dry in pots.
- (b) Seed soaked for 24 hours, then germinated in an open porous dish : sown after 6 days.
- (c) Seed soaked for 24 hours, then vernalized for 6 days at 25°C.
- (d) Seed soaked for 24 hours, then put under pressure (village method) for 6 days—control of (c).
- (e) Seed soaked for 24 hours, then vernalized for 10 days at 25°C.
- (f) Seed soaked for 24 hours, then put under pressure for 6 days—control of (e).
- (g) Seed soaked for 24 hours, then vernalized for 15 days at 25°C.
- (h) Seed soaked for 24 hours, then put under pressure for 6 days—control of (g).

Treatments a, b, c, d, e and g were laid down all at the same time, and treatments f and h were started at such times that they were sown on the same day as treatments e and g, of which they were respectively the controls.

Since the period from sowing to flowering varies with the time of sowing, a and b cannot be used for comparison, but the pairs c and d, e and f, and g and h may be compared. With the variety Kurulutuduwi these pairs shew significant differences, in favour of vernalization when the treatment is given for 6 days, but in favour of the village method when the period of vernalization is longer. In view of the fact that such differences are not to be found in the corresponding pairs in the variety Mawi, the results however are not regarded as conclusive.

The experiment was repeated in 1934 with various modifications, all treatments being sown on the same day so that only one treatment by the village method was needed, less water being used in soaking and the plants being grown in the field instead of in pots. Again small though significant differences were observed between treatments. Taking the seed sown dry as the control, a significant shortening of the period between sowing and flowering has been obtained with the seed germinated in an open dish and with that vernalized for six days: if, however, we take the normal village method (treatment c) as control, the only significant difference is obtained with the seed germinated in an open dish. There is no significant difference between the village method and the seed vernalized for 6 or 10 days, but 15 days pre-treatment has an adverse effect. Though these differences were mathematically significant they are of no value in field practice as similar differences can be obtained by variation in the sowing date. It is interesting to note that the method evolved by the villagers corresponds closely to vernalization and the period used coincides with the optimum period of vernalization. It is thought that the aim of the villagers has been improved germination, without consideration of the time of ear formation.

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In the paper reviewed above it was found that small but significant differences resulted from pre-treatment of seed and it was suggested in attempting to account for the smallness of the effect, that perhaps the temperature factor was not at the optimum value. Further experiments have now been carried out in which that suggestion has been put into effect (28a).

In the first field experiment, all treated seed was vernalized at the same (laboratory) temperature, but for different periods of time. In the experiment now recorded, all treatments were vernalized for the same period of six days (that period having produced the greatest effect) but at different temperatures. As before, the seeds were sown after treatment in plots of 144 plants spaced six inches apart both ways. The plots were replicated six times and were arranged in the form of a Latin Square. The treatments were :—

- (A) Sown dry.
- (B) Seed soaked for 24 hours, then germinated in an open porous dish.
- (C) Seed soaked for 24 hours, then kept under pressure (village method) for six days.
- (D) Seed soaked for 24 hours, then vernalized for six days at laboratory temperature (approximately 25°C.).
- (E) Seed soaked for 24 hours, then vernalized for six days at 30°C.
- (F) Seed soaked for 24 hours, then vernalized for six days at 35°C.

All treatments were sown on the 13th April, 1935. The diagram reproduced below shows the layout of the experiment, with the mean number of days from sowing to flowering inserted for each plot.

F.	E.	B.	A.	C.	D.
123.5	119.7	124.8	129.8	121.6	122.9
A.	F.	C.	E.	D.	B.
129.1	119.9	123.0	122.2	119.0	121.7
E.	C.	D.	B.	F.	A.
120.1	121.1	123.6	122.9	118.9	124.2
B.	D.	E.	F.	A.	C.
122.2	119.7	120.6	120.8	124.7	119.4
D.	A.	F.	C.	B.	E.
120.8	124.6	118.8	124.0	121.7	117.6
C.	B.	A.	D.	E.	F.
123.0	121.3	125.4	122.9	120.2	117.9

The results and the analysis of variance are given in tables. The differences between treatments are significant: the standard error of a group of six plots is 2.674 days, so that differences between treatment totals of more than 8.022 days are significant. On this basis, and taking the seed sown dry as the control, a significant shortening of the period between sowing and flowering has been obtained with all the treated seed. This result agrees closely with that obtained in the previous trial. There the seed germinated in an open dish and that vernalized for six days shewed a significant shortening; here (where all the vernalized seed received six days pre-treatment) the result has been the same with the addition of the seed treated by the village method, which corresponds closely to vernalization for six days, and which did not differ significantly from that method in the last trial. If we take the village method as control, significant shortening has been obtained with both lots of seed that were vernalized at higher temperatures. The effect of temperature is therefore a significant one, but again the difference is only of mathematical significance, and has no practical value.

A suitable technique for sesame and the application of the Odessa technique to rice are being investigated (9).

KENYA.

(676.2/9)

Experiments made by the Department of Agriculture (32) on maize and wheat according to the Odessa instructions have so far produced no results.

SOUTH AFRICA.

(68)

It has been realized for some time (21) that the germination and growth of Finger grass (*Digitaria* sp.) is comparatively slow under natural conditions, and therefore where a Finger grass pasture is put down by seed in lands that were subjected to cultivation for some time, this is not too favourable to the establishment of the pasture in the struggle against the ready germination and quick growth of weeds normally found on such old lands. An attempt was therefore made to apply vernalization.

Two experiments were laid down: one on a small plot with a control, under controlled conditions such as freedom from weeds and regular watering, and the other on a larger area, with a control, and left to natural conditions.

The pre-treated seed in each case gave a quicker germination than the controls, the pre-treated seed reached a sixty per cent germination in nineteen days on the small plot, whereas the control only reached a sixty per cent germination after thirty-eight days. However, no remarkable difference in growth was observed; both treated and untreated plots reached maturity about the same time. In the plots left to natural conditions, the stand on those sown with pre-treated seed is somewhat better than on the controls.

As the only gain is in germination-time, it is not necessary to go to the elaborate method of pre-treatment of seed, as more or less the same result can be obtained by soaking the seed in excess of water for 48 hours immediately before sowing. The seed can be dried down slightly to facilitate handling.

MAURITIUS.

(698.2)

No results were obtained in experiments with maize, stocks and tobacco owing to fungous attack (46). Seeds were soaked at 26 to 27°C. and then treated at 20 to 30°C.

CANADA.

(71)

At Ottawa, the Department of Agriculture has tested the efficacy of vernalization on various crops, with mainly negative results (12). Seeds of maize and soya beans were vernalized according to the Odessa instructions. This consisted of soaking the seed in a given quantity of water for a specified time, after which it was maintained in darkness at a constant temperature of 25°C. for a period of 15 days. An ordinary egg incubator proved to be a convenient means of providing the necessary conditions of temperature and humidity.

The effect of this treatment on soya beans was to reduce the germination from 95 to 35 per cent. Those seeds that did germinate were reduced in vigour of growth. Development of the plants was retarded throughout the season and at no time did they appear as far advanced as the check plants.

Vernalization did not affect the germination of the maize seed. The plants from

both treated and untreated seed developed equally well, but pre-treatment had no effect in increasing the yield or hastening maturity.

* * * * *

Further observations of a similar nature have been made on turnips at the Laboratories of the National Research Council of Canada (13) in co-operation with the Forage Crop Division of the Central Experimental Farm, to determine whether a pre-seeding or vernalizing treatment would cause turnips to bolt in the year of seeding. The seed was maintained at a high moisture content in a partially germinated condition at temperatures of 1°, 5°, and 9°C. for 21, 28 and 35 days prior to sowing in the field. This method may prove to be suitable for the detection of strains with an inherent tendency to bolt.

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In Alberta (19) maize was moistened to from 30 to 100 per cent; seeds were soaked at 52 to 53°F. for 30 hours and then at 80°F. for 11 days. No results were obtained. Soya beans were moistened to from 75 to 100 per cent and treated similarly. Germination was poor owing to an attack of mould.

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At the Department of Agronomy of the University of Manitoba (44), seeds of Dawson's Golden Chaff (hard red spring wheat) and Kharkov winter wheat (soft) were treated according to Lysenko's instructions for periods of 40, 45 and 50 days. The trials were made in 1933 and 1934.

The winter wheats receiving treatment produced a reasonably satisfactory yield of normal types, but the untreated did not form ears. The vernalized winter wheats were however still inferior in yield to the local spring wheats and fully three weeks later than them in maturity.

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A report has been received of experiments in progress in Ontario on spring wheat, *Triticum durum* and soya beans (49).

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In Quebec, experiments have been made with beet, sweet corn, onion and common maize (61). The first three crops were soaked to absorb 40 per cent of their moisture, and then kept at 5°C. for 5, 10, 15 and 20 days under (a) continuous light, (b) alternating light and darkness, and (c) darkness. The maize was maintained at 35°C. for 40 days in artificial light and in darkness. Results in both cases were negative.

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The results of experiments made at Saskatoon by Wort (72) for a period of one year only are available. The material used included hard spring wheat (Marquis and Reward), oats (Banner and Victory), rye (Prolific Spring and Dakold Winter), barley (C.A.C. and Hannchen) and sweet clover (biennial and semi-dwarf Alpha).

Treatment. Water was added to bring the moisture content up to 45 — 50 per cent. The seeds were kept at 15°C. for 24 hours and then placed in absolute darkness at 1 to 3°C. for from 7 to 23 days. This vernalized seed was divided into three lots. The first lot was planted in pots and exposed to normal length of day in a greenhouse. The second lot was planted in pots and kept under continuous light (daylight plus electric light) in a greenhouse. The lights were of 500 W., and were suspended 4 ft. above the pots at the beginning and therefore 1 to 2 feet from the top of the grown plants eventually. The temperature of the greenhouse varied according to the temperature outside. The third lot was planted in the field in 4-foot rows on May 5, 1934. The greenhouse plantings took place between April 10 and May 5. The field lot received no water in addition to rainfall; those in the greenhouse were watered at 5 p.m. every day. Checks were ungerminated, dry seeds.

Results :

- (1) A slight decrease in germination of vernalized seed compared with check.
- (2) Time for emergence from soil was practically the same for vernalized seed and check.
- (3) There was no significant difference in time of emergence of head from the sheath, being from -2 to 7 days, in the three lots.
- (4) Alpha sweet clover flowered from 1 to 12 days before check.
- (5) Generally there was a definite increase in green weight, which was in one case (Banner oats) 246.7 per cent over check.
- (6) In the case of Alpha sweet clover there was not a consistent increase in dry weight.
- (7) There was no significant decrease in time of ripening (-3 to 5 days).
- (8) In the greenhouse some vernalized seed shewed increases and some decreases in weight of threshed grain. The field results shewed increases in practically every case. Prolific spring rye shewed an increase of 110.88 per cent over check.
- (9) Generally the height of the vernalized plants was greater than the check and also the yield was of better quality.
- (10) In the greenhouse there was no significant decrease in time of heading and ripening for Dakold winter rye under continuous light. Under normal conditions of light the vernalized headed 14 days before the check in the greenhouse. In the field the vernalized headed 17 days before the check but the time of heading was too late to allow ripening before the frost.
- (11) No definite length of vernalization was found to be best: 23 days, 13 days and 5 days gave approximately the same results.

From these results it is concluded that although no significant decreases in vegetative period were obtained, significant increases in yield were obtained in practically every case. In Western Canada the main objective is the reduction of the time necessary to reach maturity in order to escape rust attack and the early autumn frosts. The results obtained do not indicate that this reduction in time for maturity will be achieved by the application of vernalization.

BERMUDA.**(729.9)**

According to the Agricultural Bulletin (1) the effect of cold storage of Easter Lily bulbs for one month at a temperature of 36°C. has been to bring them into bud at an early date whilst bulbs without such treatment have shewn no signs of budding. It is thought that the process may be worthy of application by florists and gardeners.

UNITED STATES OF AMERICA.**(73)**

According to McKinney and Sando (40 and 42) the earliest work on the chilling of germinated wheat seeds to convert winter into spring wheat is attributed to the American Klippart who obtained his results before 1857. Natural effects of a similar kind have been observed for years in certain areas of the United States and were mentioned by McKinney in 1920. In 1928-29 the authors of the paper under review, using Harvest Queen winter wheat seeds, tested the effects of moisture followed by a dark period at a temperature of 30 to 35°F. and then by increased temperature and winter daylight treatment of 16 to 18 hours daily. The chilled seeds headed 66 days after planting and the controls 128 days. Experiments with other varieties shewed that temperatures from 37° to 44°F. were more favourable than lower tem-

peratures for stimulating earliness in winter varieties and that the low temperatures retarded spring wheats. Heading was less at 70 to 90°F. in natural daylight than at the lower temperatures obtaining in the open, and best with continuous light at outdoor temperatures. The optimum duration of the chilling period for germinated seed is determined not only by varietal characteristics, therefore, but also by the conditions of temperature and light prevailing during the subsequent growing period.

The authors disagree with Lysenko in his view that temperature is the main controlling factor in the field; in their opinion temperature and the photoperiod together constitute the major environmental factors that condition earliness in wheat, and within limits their action is compensatory. A reduction in yield of seed due to accelerated sexual reproduction was observed, but this was less when plants were grown under suitable conditions of light and temperature during the initial growth phase than when extreme earliness had been induced in germinated seeds chilled in the dark.

The most rapid earing from chilled seeds was obtained by growing in continuous light after germination. In this way Harvest Queen winter wheat was induced to ear in 89 days from soaking but the plants had only 10 to 30 seeds each. By suitably adjusted light treatments the same variety was induced to ear one day earlier, i.e. after 88 days and to yield 75 seeds per plant.

The régime by which this was attained was as follows:

70 to 75°F. on moist filter paper for two days to start germination. 50°F. for 36 days with a photoperiod of eight hours in culture chamber. 60°F. for 18 days with a photoperiod of eight hours in culture chamber. 70 to 75°F. to end of test with a photoperiod of 18 hours in greenhouse.

Varieties differed widely in their temperature and length of day requirements for earliness. However, the tests indicate that "all the winter varieties tested complete their life cycles quite rapidly and produce good yields of seed when grown at 45 to 50°F. with a daily photoperiod of 8 to 10 hours for 43 days followed by temperatures of 70 to 75°F. with a daily photoperiod of 16 to 18 hours."

Environmental conditions tending to favour earliness also reduced the number of internodes per culm. Other physiological factors involved are growth rate of the internodes and the duration of their elongation period.

The temperature requirements are different for the various growth phases in a single plant; also varietal differences in these respects exist, and there are possible genetic bases of such responses.

"The typical spring wheats have relatively high temperature and long daylight optima during their entire life cycle, whereas the typical winter wheats have low temperature and short daylight optima during the initial growth phase and relatively high temperature and long daylight optima in the subsequent phases with respect to earliness." Winter wheats sown in spring failed to ear because of the absence of the optimum temperature and light conditions during the initial growth phases. They can be brought to ear, however, without the application of low temperature in the early stages, as has been shewn by bringing such plants into the greenhouse in the late summer and by continuous culture in the greenhouse.

In view of (a) the reversal phenomenon observed in the order of a variety when grown in different environments, and (b) the conclusion that earliness is influenced by several characters, it is evident that populations that are segregating for earliness and lateness should be tested as far as possible under several suitable conditions of temperature and day length.

* * * *

McKinney and others (41) report on field experiments with vernalized wheat. Germinated seed of a number of varieties of spring and winter wheats was vernalized and the yield compared with that of the untreated varieties.

The results, though inconclusive, suggest that many of the spring varieties now cultivated in U.S.A. are so well adapted that the vernalization of winter varieties is unnecessary and it is doubtful whether the yields of vernalized spring wheat will offer any material advantage. Improvement in the technique might make the method of some use in certain districts. The method can, however, be used with advantage for the more rapid increase of progenies and selections in breeding work.

★ ★ ★ ★ ★

In attempts to vernalize maize (Sprague 68) the treatment consistently reduced the percentage of germination, the number of visible nodes and ears, the plant height and the weight of shelled grain per plant. Pollen shedding and silking were significantly accelerated in some strains, but not enough to be of economic importance. There was no evidence of a darkness requirement for maize.

In the author's opinion though vernalization in the United States does not appear to offer any great commercial possibilities, it might have considerable value in physiological and genetic research.

★ ★ ★ ★ ★

Experiments are reported by Martin (45) to test the possibility of using vernalized winter wheat as a substitute for spring wheat or for re-seeding winter wheat which has failed. Vernalization was successful but the yields did not compare favourably with those of spring wheat, still less with those of winter wheat autumn sown. The length of time required for successful vernalization, in many varieties amounting to 65 days, is another drawback which deprives vernalization of its advantage over winter seeding or the use of a spring variety. The practical and economic difficulties of applying low temperature treatment on a large scale are mentioned as a further very serious drawback.

Experiments to test the efficacy of high temperature vernalization applied to sorghum have all so far given negative results. The process in this case moreover is still more difficult of application on any large scale.

The author is of the opinion that the value of vernalization is largely confined to its use in experimentation, as for instance by breeders to procure two generations in one year.

★ ★ ★ ★ ★

Peltier and Kiesselbach (53) have reported on experiments to induce early fruiting in winter wheat by seed activation. Germinated seed of the two winter wheat varieties Turkey and Early Blackhull was kept at a temperature of 35°F. for 60, 30, 15, and 7 days just before planting, and each of these lots was divided into three parts one of which received no further treatment, a second was frozen at 28°F. for three hours and a third frozen at -4°F. for 1 hour. All the seed was then planted on March 30 with control seed of the two winter wheats and germinated seed of Ceres and spring wheat.

All the seed kept when germinated at 35°F for 60-30 days whatever its subsequent treatment headed at about the same time as the spring wheat. No heading was observed in any of the other plots.

The experiments were repeated the following year except that the freezing was done before storage but the results were not affected.

★ ★ ★ ★ ★

Borodin (6) determined the jarovization (i.e. vernalization) formula which is represented by the predetermined combination of three factors, moisture, time and temperature, indicated in a ratio of A : B : C in which A is moisture percentage per dry weight of seeds, B time of treatment in days, and C. temperature (centigrade), for each of 35 varieties of oats and 50 varieties of barley.

The five types of response observed for both cereals are defined. The jarovization formula or pre-sowing treatment necessary to produce the vernalization

effect is specific for any one variety. Plants of winter oats grown from treated seeds are less subject to infection by crown rust (*Puccinia coronata*). The acquired properties of the seed were unaffected by a train journey of 1,979 miles, lasting seven days.

The same author (Borodin 7) subjected fifty strains of barley of four botanical species including forms from India and the Himalayas to vernalization, four different formulae (i.e. predetermined combinations of moisture, time and temperature) being used. The response of such pre-treatment is specific for any one strain.

Out of the 50 strains, seven gave a typical winter type response (i.e. full heading in the experiment and grass-cluster in the control), ten a winter-spring type response by acceleration of heading and ripening, and two a spring-winter type response by slight acceleration of heading. Thirteen strains failed to respond. Nine varieties produced heads in the experiment and control plants, i.e. a spring type response.

* * * * *

McKee (39) has made experiments which are of importance in connexion with the application of vernalization to leguminous species. These experiments were carried out in an ordinary laboratory at temperatures of from 20° to 22°C. on hulled crimson clover (*Trifolium incarnatum*) seed. Seed was germinated for varying intervals and then dried at room temperature for eight to ten days. Subsequently growth was recommenced. The seed was fully swollen after 22 hours moistening but the radicle appeared only after 27 hours treatment. Seed in which the radicle had appeared was injured by drying, and in all slightly sprouted seeds drying from 52 to 192 hours caused injury. Further tests demonstrated that seeds moistened for 42 hours and one hour respectively shewed marked differences in time of commencement of germination and in percentage germination. The seed treated for 42 hours germinated first, the one hour group later and untreated seed appreciably later still. Swelling and subsequent drying did not affect vitality of seed, and growth commenced quicker than in untreated seed. This varies in different species, for grass species recover rapidly after advanced sprouting of the radicle and plumule but certain legumes with epigeous cotyledons apparently do not restart growth easily.

BRAZIL.

(81)

Pereira (54), writing in Brazil, reports results in U.S.A. and also in Guatemala, where wheat vernalized and sown in May 1933 gave abundant ears with good grain in August of the same year.

BRITISH GUIANA.

(881)

The Department of Agriculture has studied the application of the vernalization technique to rice without any favourable results (8).

AUSTRALIA.

(94)

Vernalization experiments were made at Canberra by McMillan, Christian and Hills (43) on wheat (Early Bird, Waratah and Cleveland), maize, tomato, soya bean, field peas, Sudan grass and Japanese millet. The Lysenko technique was used throughout.

In all crops but one, there was no significant difference between the untreated and the treated (vernalized for short or long period or "germinated for 24 hours") for either maturity or yield. Only "Early Bird" wheat shewed any significant difference; the "germinated for 24 hours" was significantly greater than the untreated and the vernalized in yield. The difference was due to a greater ear number per plot, but the result is not considered to be of any importance owing to the fact that the experiment was sown very late.

It is therefore concluded that vernalization according to the methods described by the Imperial Bureau of Plant Genetics does not produce any significant results under Canberra conditions.

* * * * *

Forster and Vasey (23 and 24) made observations on the time of earing of an Australian and English spring wheat and an English winter wheat when sown at 7-10 day intervals throughout the year. One lot was sown under normal daylight and the other under a constant illumination of 16 hours daily. In the autumn sowings the plants in the longer day headed 38 days earlier than the normal plants, the difference becoming less pronounced in the later sowings. That temperature also acted in the direction of hastening earing was shewn by the earlier heading of the plants sown in summer, which eared 60 days earlier than those sown in winter. Plants of the winter variety sown after September failed to come into ear but this behaviour was not shewn by the spring varieties.

The results shewed that germination and the period from heading to maturity were influenced by temperature alone, while the rosette and jointing stages were affected both by temperature and length of day. Soil temperatures of over 15°C. prevented heading in winter but not in spring varieties, the limiting temperatures for the two spring varieties used being determined at 25° and 28°C. respectively. The method of vernalization is therefore thought to be inapplicable to the Australian wheats, all of which are spring forms, but by making use of the behaviour here described it is possible to grow two and sometimes three generations in a year.

Many apparently uniform varieties have proved markedly heterozygous in their response to the above treatments. Such heterozygosity is often manifested even as a result of a change in environmental conditions, when it is followed by natural selection of the types most adapted to the new conditions. In illustration of how natural selection acting in this way can change the constitution of a variety reference is made to a strain of Red Marvel wheat grown for two generations in Australia and which came into ear twelve to seventeen days earlier than the original strain grown from seed obtained direct from England.

Vernalization in countries other than the Soviet Union.

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- Agropyrum tenerum* 80.
Alopecurus pratensis 73, 74, 77, 78, 79.
Anãropogon sorghum (see sorghum).
A. sorghum var. *Sudanensis*, 73, 88, 123, 142
Arachis hypogaea 123.
 Artichokes, 18, 122.
Avena byzantina 26, 54, 55.
A. grisea 26.
A. sativa (see oats).
 Barley, 41, 43, 47, 50, 51, 52, 58, 69, 70, 96,
 101, 102, 103, 104, 115, 116, 117, 121, 125,
 126, 132, 133, 138, 141, 142.
 Beetroot 87.
Beta (see sugar beet).
Brassica spp. 81.
Brassica napus var. *oleifera* 34.
B. oleracea 56.
Bromus 80.
Camelina sativa 89.
Carthamus tinctorius 89.
Cicer arietinum 89.
Coriandrum sativum 89.
 Cotton 10, 12, 14, 40, 47, 48, 49, 60, 81, 82,
 83, 84, 85, 96, 97, 123, 124, 134.
Dactylis glomerata 23.
Digitaria spp. 137.
 Easter Lily 139.
Eleusine coracana 134.
Eruca sativa 89.
Ervum lens 86, 89.
Festuca pratensis 73.
Glycine soja (see soya bean).
Gossypium (see cotton).
Helianthus annuus 89, 124
 Hemp 21, 96, 122, 124.
Hibiscus cannabinus 15.
Hordeum (see barley).
H. pallidum 24, 25, 26, 27, 34.
 Hops (*Humulus*) 18.
 Lettuce (*Lactuca*) 123.
Linum usitatissimum 69, 87, 89.
Lolium perenne 80.
Lupinus 19, 124.
 Maize 12, 18, 36, 60, 88, 96, 97, 115, 119,
 122, 123, 124, 129, 133, 134, 137, 138, 141,
 142.
Medicago spp. 73, 80.
Melilotus spp. 73, 80, 138.
 Melon 21, 122, 123.
 Millet 12, 13, 36, 38, 39, 41, 47, 50, 51, 67,
 72, 80, 88, 116, 123, 129, 134, 142.
 Mustard 43.
 Oats 35, 36, 37, 43, 44, 51, 58, 66, 69, 96,
 101, 102, 116, 117, 121, 125, 133, 138, 141.
 Onion (*Allium* sp.) 138.
Onobrychis 73, 80.
Oryza sativa (see rice).
Panicum spp. (see millet).
Papaver 37, 89.
Pennisetum typhoideum 134.
Perilla ocymoides 20
Phaseolus spp. 37, 38, 50, 97, 118, 122.
Phleum pratense 73, 75, 77, 78, 79, 80.
Pisum sativum 19, 51, 118, 123, 142.
Poa 80.
 Potato 19, 38, 44, 45, 67, 100, 105, 121,
 126, 128.
Raphanus sativus 56, 101, 102.
 Rice 73, 128, 133, 134, 135, 136, 142.
Ricinus 124.
Robinia pseudoacacia 19.
 Rye 23, 28, 31, 33, 34, 51, 69, 100, 102, 109,
 116, 119, 126, 128, 138.
Secale cereale (see rye).
 Sesame 136.
Solanum spp. (see potato and tomato).
 Sorghum 73, 88, 123, 126, 128, 129, 134, 141.
 Soya bean, 12, 13, 14, 15, 20, 21, 38, 39, 42,
 43, 44, 50, 51, 60, 88, 96, 97, 115, 118,
 119, 122, 123, 124, 126, 129, 137, 138, 142.
 Spinach 101, 104.
 Stocks (*Matthiola* sp.), 137.
 Sugar or fodder beet 27, 28, 101, 102, 104,
 120, 121, 124, 129, 138.
 Sugar cane 134.
 Sweet corn 138.
 Tobacco 122, 137.
 Tomato 45, 119, 142.
Trifolium incarnatum 142.
T. pratense 73, 76, 77, 79, 124.
Triticum spp. (see wheat).
Triticum $\times$ *Agropyrum* hybrid 47.
Triticum $\times$ *Secale* hybrid 33, 107.
 Turnips 73, 76, 101, 102, 138.

Ullucus tuberosus 36.

Vicia spp. 34, 73, 80.

Wheat 11, 13, 20, 27, 28, 31, 33, 45, 47, 48,
49, 52, 53, 54, 58, 59, 60, 61, 63, 64, 65, 66,
67, 69, 93, 94, 96, 97, 98, 100, 101, 102,
105, 107, 108, 109, 110, 111, 115, 117, 119,
121, 123, 124, 125, 126, 128, 129, 130, 132,
133, 134, 137, 138, 139, 140, 141, 142, 143.

Wheat species, sub-species and varieties.

Apulicum 26.

Arnautka 63.

Caesium 65, 66, 68.

Durable 61.

Erythrospermum 12, 14, 17, 33, 34, 51, 66,
107, 109.

Ferrugineum 55, 66.

Girka 62, 66.

Hostianum 58, 61, 109.

Jurjevka 61.

Kooperatorka 14, 24, 25, 26, 27, 28, 29, 30,
31, 32, 33, 54, 58, 64, 95, 109.

Leucurum 26.

Lutescens 28, 29, 30, 31, 32, 33, 54, 61, 62,
65, 66, 68, 107, 109.

Marquis 54.

Moskovskaja 33, 109, 111.

Novokrymka 11, 16, 49, 62.

Stepnjačka 14, 50, 62, 66.

Ukrainka 14, 21, 27, 34, 58, 61, 62, 64, 109,
111.

Uljka 62.

Zea mays (see maize).

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